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THE RECORDING AND PRODUCTION OF GRAMOPHONE RECORDS

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681.854:621.395.625.3

Philips' Phonographic Industries are a comparatively young branch of the Philips' concern. They are engaged in the manufacture of gramophone records, both of the old, fast-running type (78 r.p.m.) and of the modern, long-playing records. The latter type, particularly, have reached a very high quality of reproduction. An essential factor in the manufacturing process, as explained below, is magnetic sound-recording.

Three stages can be distinguished in the manufacture of gramophone records: the actual recording, the preparation of the matrix from the recording and, finally, the actual mass-production — the pressing of records. These three stages will be discussed in turn.

Recording

The studio

The quality of reproduction of a gramophone-record is very largely dependent upon the acoustical properties of the recording studio. Acoustical imperfections during a musical performance attract far more attention when there is no visual contact, as is the case with gramophone music, than when the music is listened to directly. As is well known from broadcasting and allied activities, it is very difficult — if not impossible — to take all the necessary measures to guarantee good acoustical properties during the actual construction of a studio. Added to this, the conditions vary with the extent to which the hall is occupied, so that in recording for gramophone records (when there is not, as a rule, an audience), the sound-pictures are often totally different from those produced during a performance before an audience. For example, in the absence of an audience the reverberation time of high sound-frequencies will be longer. The liberal use of curtains to replace the acoustical properties of the audience's clothing is customary. Measures must likewise be taken to suppress undesirable resonance phenomena of the studio, especially of the floor and platform. A sound-picture distorted by this kind of phenomena will interfere but little during direct listening to a performance, since it occurs only sporadically; however, in a gramophone record, finding its way to the public in many thousands of copies, this fault will be multiplied, as it were, by the number of copies sold and by the number of times that each record is played.

Clearly, precautions must be taken to make the acoustics during the recording as favourable as possible. In view of the fact that this may involve costly alterations to convert a hall into a recording studio, it is understandable that gramophone record manufacturing companies are ever on the look-out for halls which already possess most of the desired properties. This explains why different companies sometimes make their recordings in the same hall.

The above remarks apply to records of serious music. Dance music and other types of popular entertainment require quite different conditions. Usually a hall with a very short reverberation time (a so-called "dry" room) is employed for this kind of music, the desired reverberation being added electronically. Use is made here either of a "reverberation chamber" or a "reverberation channel", using magnetic recording. This brings us to the field of trick effects, which especially in recent years has found wide application in the recording of modern popular music. Electrical and acoustical "décor" are also included under this heading. With these techniques it is possible to make records which will reproduce a sound-picture that the artistes themselves could never achieve in a live performance.

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"Electrical décor" consists of a signal which is directly mixed by electrical means with the signal to be recorded. In "acoustical décor" the mixing is brought about indirectly, via an acoustic link (loudspeaker in the studio). The signals for both electrical and acoustical décor are usually derived from a recording which was prepared beforehand; acoustical décor, however, can be reproduced (often in a special studio) while the actual recording is in progress.

The microphones

The quest for ever-better quality has led to the almost exclusive adoption of condenser-microphones [1]). The latter may be classified according to their directional response into multi-directional, bi-directional and uni-directional types (with roughly circular, figure-eight shaped or cardioid polar diagrams respectively). These types are variously used to counter the acoustical shortcomings of the hall, in the attempt to give the listener the same complete impression of what is offered, although he has no visual contact with the performers. In other words, the sound-picture recorded on a gramophone record, should not be merely as faithful a replica as possible of the performance, but should accentuate certain points so that the listener may find the result satisfying.

For the same reason a number of microphones are sometimes used simultaneously: by mixing, it is sought to improve the sound-picture. There is also the danger of augmenting undesirable effects however; recording with two or more microphones is therefore entrusted only to experts with considerable experience in this field. It is also often necessary to correct the sound-picture with respect to the frequency, so that the most favourable final balance is obtained over the whole frequency range. In general these corrections consist of slow variations in amplification with frequency, but in recent years it has also been the practice to carry out corrections within a relatively narrow range of frequencies.

Magnetic recording

The sound-picture balanced in the manner described above, is nowadays recorded first on magnetic tape [2]). The prosperity of the gramophone record industry in latter years is founded upon the development of the long-playing record [3]), and it would be no exaggeration to say that without magnetic recording, its rapid fruition would have been impossible.

Earlier recordings were made by a process of direct engraving — first on a wax disc and later on a lacquer disc. The subsequent manipulations in the manufacturing process allowed only a relatively small number of pressings to be made, so that the record was doomed to removal from the catalogue after only a few years. The situation is completely different when a recording is made on magnetic tape. From a tape-recording a practically unlimited number of new matrices can be prepared as soon as those in use are in danger of showing signs of wear.

Magnetic recording has a further inportant advantage. Even the best musicians are unable in general to play faultlessly for longer than some 10 minutes; a period of 15 to 20 minutes would be very exceptional. That there should be faults during performances of longer works is something which concert audiences accept as perfectly normal; usually minor errors are forgotten at once. When recording for gramophone records, however, faults are not acceptable, on account of the enormous multiplication factor referred to above; once the gramophone listener has noticed a fault, it will annoy him more and more intensely each time he plays the record.

To obtain two acceptable lacquer discs by a direct engraving process (at least two discs are necessary, one being a reserve), it was often necessary for long passages of the music to be re-recorded several times, since none of the playing faults could be corrected on the disc. Magnetic recording has an enormous advantage over this method, in that it allows the recording to be *edited*, i.e. spliced together in sections. Advantage is taken of this for the repetition of any passage in which a fault has been made, the repetition being subsequently fitted into the recording. In this way, flawless, magnetic recordings with a playing time of about half an hour can be obtained, this being of the greatest significance for the manufacture of long playing records.

Because of the risk that the recording might be spoiled be coughing and other noises, the public are not usually admitted into the hall during the recording; in any case, the repetitions of parts of the performance would of course greatly reduce its entertainment value [4]).

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[1]) See Philips tech. Rev. **9**, 330-338, 1947/48.

[2]) See, for example: D. A. Snel, Magnetic sound recording equipment, Philips tech. Rev. **14**, 181-190, 1952/53; W. K. Westmijze, The principle of the magnetic recording and reproduction of sound, Philips tech. Rev. **15**, 84-96, 1953/54; W. K. Westmijze, Studies on magnetic recording, Philips Res. Rep. **8**, 148-157, 161-183, 245-269, 343-366, 1953.

[3]) See for example, L. Alons, New developments in the gramophone world, Philips tech. Rev. **13**, 134-144, 1951/52.

[4]) The only exceptions are historical occasions or performances of unique occurrence, the recordings of which are principally of documentary value. The circumstances under which such a record has been made, are usually reported on the label of the record.

In view of the fact that a gramophone record is actually derived not from the sound-picture direct but from the magnetic recording of the sound-picture, the very highest quality is necessary for the magnetic recording. Linear and non-linear distortion must be reduced to the absolute minimum. The same applies to brief fluctuations in the speed of the tape, which would lead to annoying variations in pitch ("wow" and "flutter").

During recording, the tape is run across a playback head and the reproduction is studied in a separate room. In judging the recording, it is taken into account that the future gramophone record will generally be played in living-rooms and must therefore give the greatest possible satisfaction under the circumstances obtaining there.

In practice however these circumstances cannot be realised in the listening room. In addition a fairly high sound level is chosen, so that any playing faults are most certain to be observed; however owing to the physiology of the ear this will mean that the observed sound-picture is not wholly accurate. The recording engineer must therefore translate the observed sound-picture, as it were, into one of lower sound level, more suitable for the living-room. Remembering also that the electrical and electro-acoustical properties of the future record owner's equipment are unknown, it will be clear that accurate adjustment of the sound-picture requires great practice.

Dynamic range

When recording it is necessary to reduce the "dynamic range", i.e. the intensity ratio of the strongest to the weakest passages. The excellent properties of magnetic tape with high-frequency bias [2]) allow it to record almost the whole dynamic range of a large symphony orchestra (about 70 dB). However, the fact that the record will eventually be played under the conditions obtaining in a living-room, means that the dynamic range of the record itself must be appreciably limited, if the reproduction is not to be marred by too strong a non-linear distortion or drowned in the surface noise or the living-room sounds which can never be completely avoided.

A simple calculation will clarify these problems. Let us assume that the output of the average reproduction apparatus (radiogram or record player and radio set) amounts to 3 W and that this output is just reached in the strongest passages. For a dynamic range of 40 dB on the record, the pianissimo passages of the music would become so soft as to be completely dominated by all kinds of interfering sounds such as are normally present in a house: street noises, sounds from neighbouring apartments or houses, and even the faint hum of the gramophone motor itself. (It should be noted in this connection that the surface noise of modern plastic gramophone records is appreciably weaker than that of the older records and can be neglected here.)

In general therefore it is assumed that a gramophone record should have a dynamic range of not more than 30 dB. Were the dynamic range any greater, the listener would tend to increase the volume of reproduction somewhat during soft passages, with the result that the sound would be much too strong and, moreover, distorted during loud passages. The listener would then reduce the volume. This undesirable situation can be avoided by doing what the listener would otherwise have to do, during the actual recording, but in an expert manner with due consideration for the music. Only when the dynamic range of the reproduction has thus been reduced can it afford the listener undisturbed enjoyment.

From the magnetic recording to the matrix

Once a musical performance has been recorded magnetically, the next step is the transfer of the recording to a matrix which can then be employed to press out the gramophone records in a plastic material. This step is divided into a number of intermediate stages, the first being the production of a lacquer disc. The matrix is prepared in a number of chemical and plating processes from the lacquer disc.

Engraving the lacquer disc

The sounds recorded on the magnetic tape are transferred to the lacquer disc via a replay head, an amplifier and a groove-cutter (*fig. 1*). The lacquer disc turns at the same speed as the gramophone record which will be manufactured from it.

During this engraving process the necessity again arises for a very constant speed, both of the tape and of the disc. Moreover, exacting precautions must be taken to avoid vibrations (these largely determine the noise level of the unmodulated groove) and to ensure that the disc is flat. The latter is of especial importance for long-playing records; the profile of the micro-grooves (*fig. 2*) — of which there may be as many as 14 per millimeter — must be constant within very narrow limits. For this reason, the turntable of the cutting machine must be made very flat and must be accurately perpen-

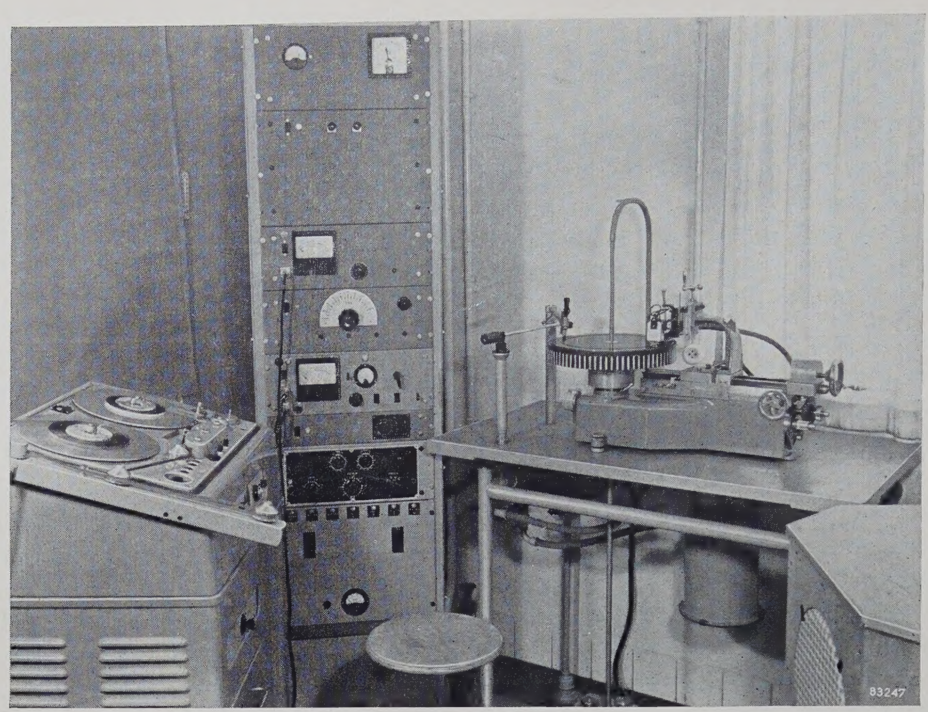

Fig. 1. Equipment for the transfer of magnetic recordings onto lacquer discs. From left to right: the machine in which the magnetic recording is played back, the amplifier rack (also containing other electronic apparatus), the machine on which the lacquer disc is engraved, and a monitoring loudspeaker.

dicular to the axis of rotation; the lacquer disc is drawn tight onto the turntable by suction.

The spectrum to be registered ranges from about 30 c/s to about 16 000 c/s. This wide range places high demands on the electronic apparatus and on the groove-cutter, especially because linear and non-linear distortion must be kept extremely low. (Linear distortion is here taken to mean deviation from a standardized frequency response curve).

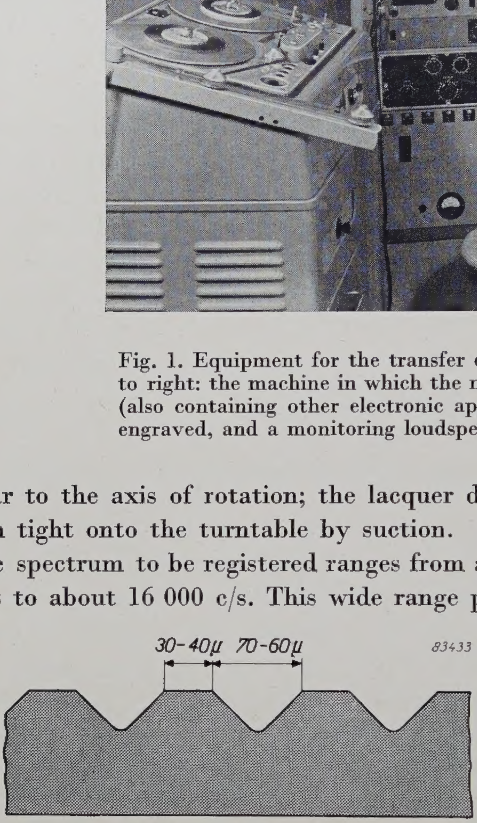

Fig. 2. Cross-section of unmodulated grooves in a long-playing record.

As regards this standardized frequency response curve, it should be noted that present-day gramophone record factories assume a *reproduction* channel with specific properties, which it is hoped will be established on an international basis. Two proposals for such a standard, one European and the other American (*fig. 3*), have been studied by the International Electrotechnical Commission, but no decision has yet been reached. When the lacquer disc is being engraved, a correction is applied which is the reciprocal of this standard, with a view to rendering the reproduction via the standard channel as far as possible independent of the frequency.

The groove-cutter is of the electrodynamic type. The problems involved in its development are of the same nature as those associated with the cutter in the Philips-Miller system [5]: the moving mass must be very small and the coil must have a high current-carrying capacity. On account of the extent of the frequency range, however, the requirements for the disc groove-cutter are still higher.

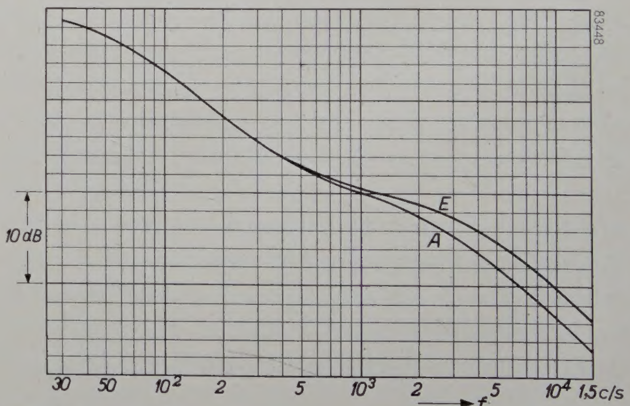

Fig. 3. Proposals for a standard reproduction channel for long-playing records, submitted to the I.E.C. for consideration. The speed v of the needle point for a constant sound intensity is plotted along the vertical axis. Along the horizontal axis the frequency f is plotted. Both are on a logarithmic scale. Curve A corresponds to the American proposal, curve E to the European proposal.

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[5] Philips tech. Rev. **1**, 135-141, 1936.

The following very approximate calculation will show that the coil is subjected to large currents and accelerations. For the sake of simplicity, only the moving mass of the copper wire of the coil is considered, so that the results will be somewhat on the low side.

If l is the length of wire on the coil, I the alternating current passing through it, and B the magnetic induction of the field in which the coil is located, then the force F which acts upon the coil (in Giorgi units) is:

$$F = IlB.$$

If the current density is denoted J, the total mass of the copper wire m and the density of copper d, then $Il = Jm/d$, and

$$F = \frac{JmB}{d}.$$

Moreover $F = ma$, when a is the acceleration; hence $a = JB/d$, or

$$J = \frac{ad}{B}. \quad \dots\dots\dots \quad (1)$$

The acceleration a may be expressed as $\omega^2 A$, where ω is the angular frequency of the note being recorded and A the amplitude of the groove. To obtain a sufficiently high amplitude, the acceleration a should be as large as possible. An upper limit to the value of a is set by the tracing distortion (see p. 138 of the article cited in [3]), which occurs whenever the radius of curvature of the recorded sine curve becomes less than the radius of the spherical needle point with which the gramophone record is later traced during reproduction. The radius of curvature ϱ of the sine curve is smallest at the peaks; thus it is there that the limit is most likely to be exceeded. At the peaks we have approximately

$$\varrho = \frac{V^2\sqrt{2}}{a},$$

where V is the speed at which the groove passes beneath the needle. In the limiting case ϱ is thus equal to the radius r of the needle point, the minimum speed must be taken for V, i.e that of the innermost grove (V_i), and the maximum value for a, viz. $a_{\max}$. Then:

$$r = V_i^2\sqrt{2}/a_{\max}$$

or

$$a_{\max} = \frac{V_i^2\sqrt{2}}{r}. \quad \dots\dots\dots \quad (2)$$

Substituting the following values in (1) and (2):

d = 8900 kg/m³ (copper),
B = 1 Wb/m² (= 10 000 gauss),
V_i = 0.22 metre/sec (for a record with 33⅓ r.p.m.),
r = 25×10^{-6} m,

we find a maximum acceleration of:

$$a_{\max} = 2740 \text{ metres/sec}^2,$$

or 280 × the acceleration due to gravity. The maximum current density is given by

$$J_{\max} = 24.2 \text{ A/mm}^2,$$

neglecting, as stated earlier, moving masses other than that of the copper wire of the coil.

In the groove-cutter in its present form as produced by Fonofilm of Copenhagen the difficulties have been satisfactorily overcome, thanks to the following measures: new, very light construction materials of great strength have been used; the components have been very carefully finished, as a result of which undesirable air gaps have been avoided and consequently the magnetic induction can be raised to a high value. In addition, negative feedback is applied [6]): attached to the cutting tool there is a small coil located in a magnetic field. A voltage is set up in this coil which is proportional to the speed of the cutting stylus. This voltage serves as the negative feedback in the amplifier which feeds the groove-cutter. This reduces linear and non-linear distortion of the engraving process to a very low level; measurements have shown that the intermodulation is about 1%.

Another special feature is the electrical heating of the point of the cutting stylus (sapphire). Thanks to this heating a smoother groove is formed, resulting in less surface noise. Moreover the reproduction of high notes is improved. In its cold state the lacquer is not purely plastic but still somewhat elastic. Under these conditions the amplitude of the groove becomes smaller immediately after cutting, the reduction in size being more pronounced at smallest wavelengths. This phenomenon therefore occurs particularly at high notes and for the innermost grooves, where the wavelength is shortest. Heating the stylus renders the lacquer so soft that this undesirable effect is avoided. The lacquer regains its original hardness at a very short distance behind the stylus.

To lengthen the playing time of gramophone records, the system of *variable groove pitch* has found application in recent years. In this system the average distance between two consecutive grooves is made to depend on the amplitude and is kept as small as possible. This means that in soft passages more grooves are engraved per millimeter than in the usual system in which the groove separation is constant and based on the loudest passages [7]).

The variation of the groove separation with amplitude is, of course, done automatically. Before passing the replay head, the magnetic tape passes over an auxiliary replay head which gives a pre-indication of the strength of the signal about to be cut in the disc. The alternating voltage produced in the auxiliary replay head is rectified and the variable rectified voltage so obtained determines the frequency of a valve oscillator. The latter supplies a synchronous motor via an amplifier, and the number of revolutions of the motor is thereby made to depend on the strength of the signal about to be cut. The motor drives the mechanism which displaces the cutting-stylus radially in the required direction.

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[6]) F. Schlegel, Einige Schallplattenaufnahmeprobleme, Acustica 4, 45-47, 1954 (No. 1).

[7]) The average extension in playing time thereby achieved is about 20 % for classical works.

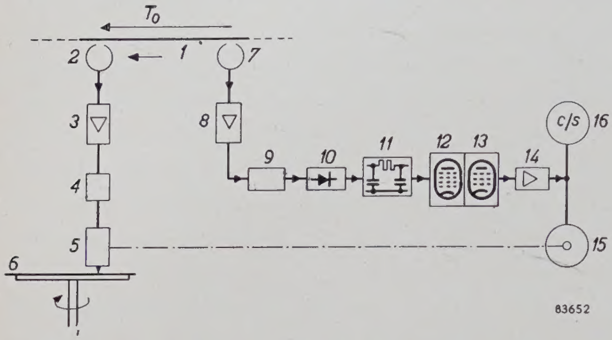

Fig. 4. Block diagram of the equipment for transferring the magnetic recording (*1*) to a lacquer disc (*6*) via replay head *2*, amplifier *3*, corrective network *4* and groove-cutter *5*. The equipment for variable groove pitch is on the right: *7* auxiliary replay head, situated about one revolution (T_0) of the disc ahead of head *2*; the signal from *7* passes through amplifier *8*, filter *9*, rectifier *10* and delay network *11* to the reactance tube *12*. The latter regulates the frequency of a valve oscillator *13*, which supplies a synchronous motor *15* via an amplifier *14*; the synchronous motor displaces the groove-cutter radially; *16* frequency meter.

Fig. 4 is a block diagram of the installation for variable groove pitch. Between the rectifier and the reactance tube (the tube which governs the frequency of the oscillator) there is a delay network, whose time constant is approximately equal to the time required for a certain point on the tape to cover the distance between the two replay heads; this time T_0 is selected roughly equal to the time for one revolution of the disc.

Fig. 5 shows the delay network in greater detail. The amplified and rectified signal V_s from the auxiliary replay head is applied to C_1. The capacitor C_2 gets a delayed charge, via a resistor R_1. As the signal V_s increases, the grid potential V_{g3} of the reactance tube gradually becomes less negative, and this increases the frequency of the oscillator; the speed of the synchronous motor and the groove separation *s* are proportional to this frequency.

Also indicated in the circuit are a threshold voltage V_d and a limiting voltage V_{lim}. The former is a direct voltage which opposes V_s; as a result the groove distance which had initially been adjusted to a very small value, only begins to increase when the amplitude exceeds a certain level. The limiter consists of a diode in series with a source of direct voltage V_{lim}; this ensures that the oscillator frequency and the groove distance do not increase indefinitely as a function of the signal amplitude. *Fig. 6* shows the influence of the threshold voltage and the limiter. In *fig. 7* the voltage-time functions of various points in the circuit are shown.

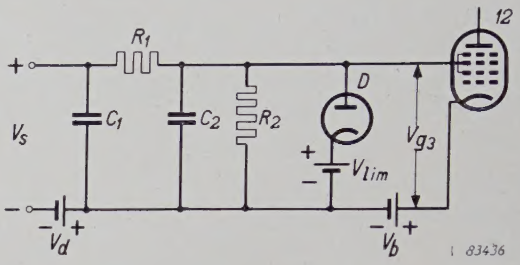

Fig. 5. Circuit of the delay network *11* of fig. 4. V_s input signal (varying direct voltage). V_d threshold voltage. C_1 capactitor from which capacitor C_2 is given a delayed charge via resistor R_1. R_2 discharge resistor. The diode *D* with bias V_{lim} forms the limiter. V_b grid bias. *12* reactance tube.

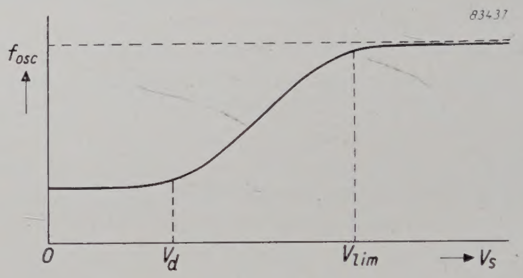

Fig. 6. The frequency f_{osc} of the oscillator (*13* in fig. 4) as a function of the signal voltage V_s. The threshold voltage is V_d, the limiting voltage V_{lim}.

The preparation of the matrix

The matrix is prepared from the lacquer disc by electroplating and press techniques. The lacquer disc must first be rendered conducting. The modern method is roughly the same as that by which silver mirrors are made, namely by precipitation of silver from an ammoniacal solution of silver nitrate. Processes which take place in vacuo, such as silver-

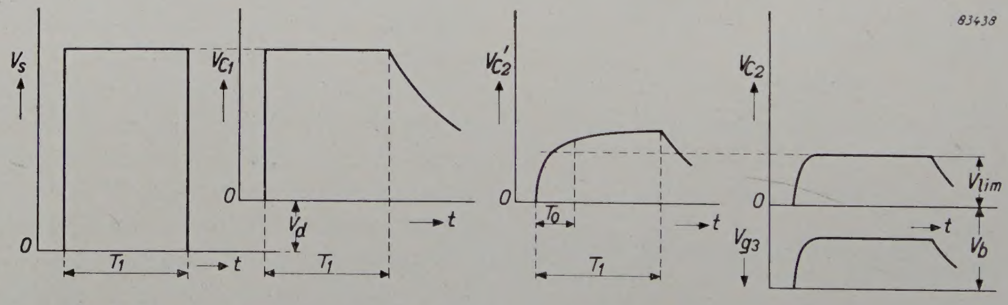

Fig. 7. Various voltages in the circuit of fig. 5, as functions of the time *t*, for a fortissimo passage (duration T_1; the revolution time of the record is T_0).

V_s = signal voltage. V_{C_1} = voltage across capacitor C_1. The voltage across C_2 would be as that shown for V_{C_2}' if no limiter were present; with the limiter the voltage is as shown for V_{C_2}. The voltage between grid and cathode of the reactance tube is V_{g3}; this voltage determines the frequency of the oscillator.

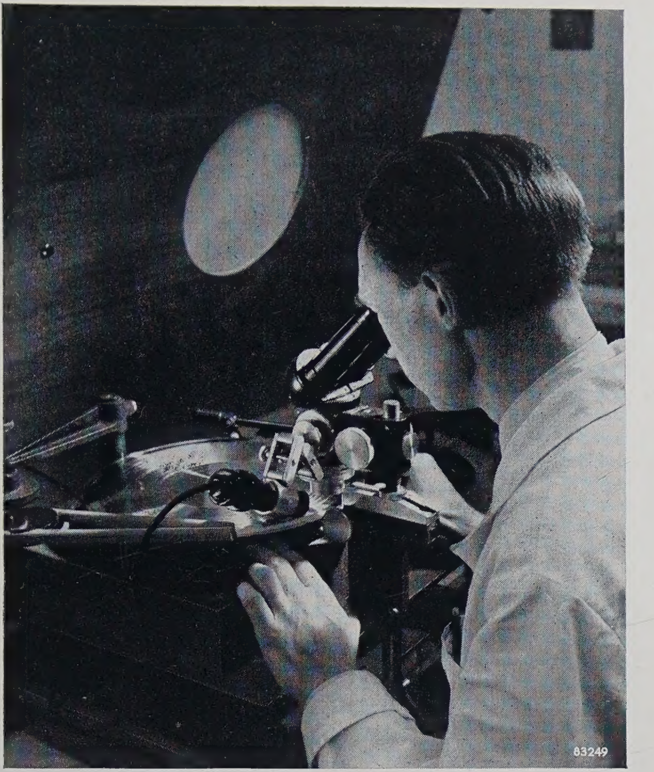

Fig. 8. Checking the positive for damage and dust particles.

ing by cathodic sputtering or evaporation onto the disc have for all practical purposes been abandoned, since both the vacuum and the temperature rise associated with these methods have an unfavourable influence on the lacquer disc.

When the lacquer plate has been covered with a layer of silver — only a fraction of a micron in thickness — a layer of nickel, followed by a layer of copper, are electro-deposited on the disc. The lacquer plate can now be separated from the metal. The thin coating of silver comes away with the metals which have been built up on it. A metallic copy of the lacquer disc is thus obtained, with the difference however that the copy bears ridges instead of a grooves; it is therefore called the negative.

In principle it is possible to use this negative as a matrix, for an impression of it in a plastic material would be an exact positive replica of the original, i.e. the lacquer disc. This procedure is followed, however, only if the record is to be issued in small numbers. The method is not followed for larger issues because, should the negative be damaged during pressing there would be no "reserve"; it would then be necessary to make a new lacquer disc engraving and to prepare a new negative from it (the latter operation can generally be performed only once on a lacquer disc), and the manufacture of this particular record would be held up during this time. To avoid this, a metal positive is first prepared from the negative, by an electro-forming operation on the negative, again of nickel and copper. (To avoid fusion of the positive and the negative, the latter is first covered with a layer of a separating agent.) In this way a positive is obtained which is in fact a metal gramophone record (with grooves on only one side), which it is possible to play. This is in fact done in order to check the positive for irregularities which might have arisen during the plating processes; these irregularities are if necessary corrected. With the aid of very fine engraving tools and a microscope, particles of dust and other extraneous matter can be removed from the groove (*fig. 8*). A metallic negative is now prepared from the positive in the same way as the positive was derived from the negative. This second negative is the pressing matrix or stamper (*fig. 9*). The copper back of the matrix is rendered absolutely plane parallel with the front side on a special lathe. The centre is then determined by an optical method (*fig. 10*), this being the point with respect to which the groove forms an equiangular spiral, and the centre hole punched (on a disc with variable groove distance there is always a part with constant groove distance, which can be used for determining the centre). The outer edge is then turned to size. To improve the durability, the matrix is finally plated with a layer of chromium, a few microns thick.

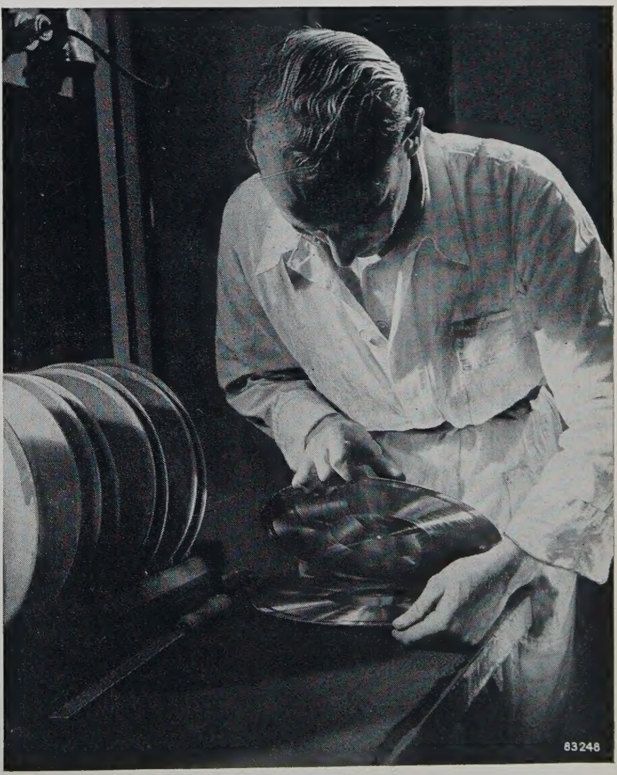

Fig. 9. Separation of the positive and the electroformed stamper.

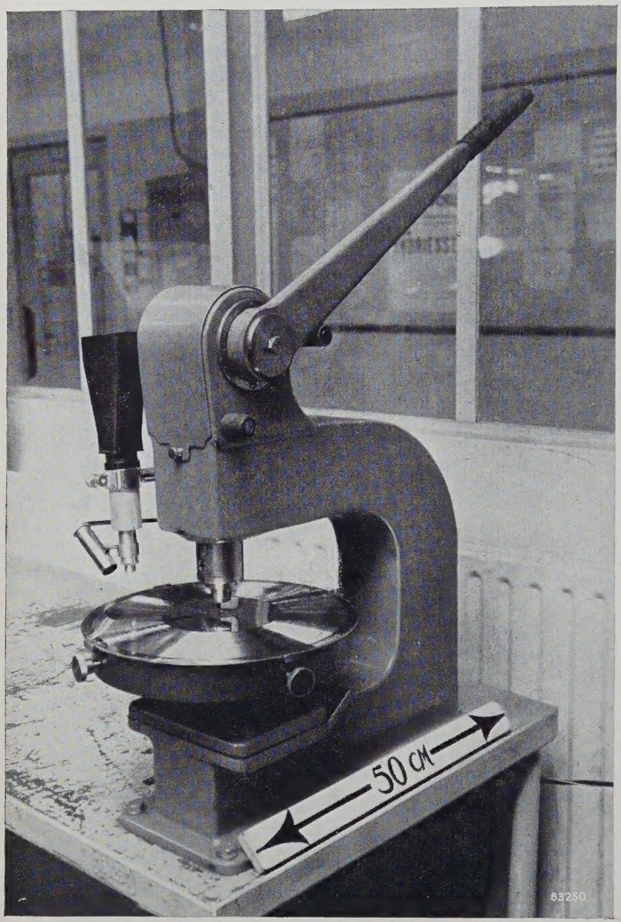

Fig. 10. Centring a matrix. The latter is loosely champed to a rotatable table. The position is altered until on turning the table, the grooves, viewed through a microscope, are seen to move in one direction only (either inwards or outwards). The lever is then pulled down, punching out the centre hole.

Should the matrix be damaged during manufacture a new one can be made without occasioning a long delay, from the metal positive. The latter, like the metal negative from which it was derived, suffers no damage whatsoever from the electroforming copying process. Should the positive also be unsuitable for use when a number of matrices have been made from it, there is a further reserve in the form of the metallic negative.

The mass-production of gramophone records

Before discussing the pressing, i.e. the mass-production of the actual gramophone-records, let us first say a few words on the materials from which the discs are pressed.

Pressing materials

Two kinds of material are employed nowadays for the manufacture of gramophone records. The older is a shellac material, the more modern a synthetic resin, which is actually a copolymer of vinyl chloride and vinyl acetate. Apart from giving a very smooth surface (thus an almost noiseless groove), the synthetic material has the added advantage of being unbreakable [3]).

The methods of preparation of these materials differ considerably. The shellac material consists principally of shellac, copal resin, a pigment and a filler. These constituents, having been very finely ground, are mixed while still dry. The mixture is then plasticized and kneaded in a rolling plant with one heated roller; the stiff mass is then fed to a special type of calender which cuts the material into tablets of the size required for one gramophone record. In the preparation of the synthetic resin the constituents — principally copolymer powder — are mixed with a pigment and a stabilizer, the latter to ensure that the copolymer does not decompose during the manufacturing process, giving off chlorine, which is harmful. The material then passes through an extrusion press where it is heated and plasticized prior to extrustion; it then passes through a cutting machine. It leaves the latter in the forms of grains about 5 mm in diameter. This is the basic material for long-playing records. The material is examined for the presence of undesirable particles of metal by means of a metal detector [8]).

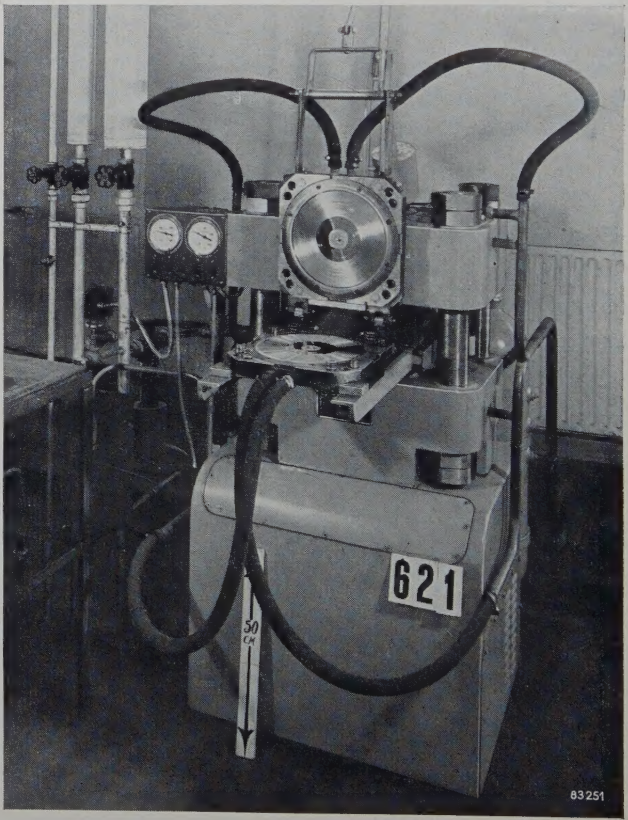

Fig. 11. Gramophone record press shown open.

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[8]) E. Blasberg and A. de Groot, Philips tech. Rev. **15**, 97-104, 1953/54 (fig. 8).

The pressing

Gramophone records are pressed in hydraulic presses (*fig. 11*) of the order of 100 tons capacity. The presses are equipped with moulds to which the matrices are fixed. The material to be pressed is pre-heated, the shellac tablets on a steam-heated table, the synthetic resin grains in an electric oven. The pre-heating is necessary to accelerate the pressing cycle and more especially to save the matrices, which would wear rapidly against the hard, cold material.

Prior to pressing, the matrices and the corresponding labels are attached to the moulds and the pre-heated material (either a shellac tablet or a suitable amount of granular resin) is fed in. During these operations the moulds are steam heated, the heating being continued during the pressing operation itself. The hot material spreads out rapidly over the whole surface, so that it completely fills the mould; the steam is then shut off and cold water is fed in to cool the moulds and matrix rapidly to a temperature at which the record has become sufficiently solid to be removed from the press.

The edge of the record is freed from extruded material and carefully finished on a polishing machine. This is followed by the visual inspection of each record, packing in covers and delivery to the store. At regular intervals a check is conducted in which records are selected at random and tested for musical quality.

Summary. The chain of operations in the manufacture of gramophone records is described. The music is recorded magnetically on tape, and subsequently transferred onto a lacquer disc by means of a groove-cutter. A metal negative is prepared by an electroplating on the lacquer disc; from this negative a positive and a further negative are made by electroforming. The last negative is the matrix (stamper), with which the gramophone records are pressed out in a hydraulic press. Some records are still manufactured from shellac, but the modern synthetic resin material — a copolymer of vinyl chloride and vinyl acetate — is becoming increasingly used for long-playing records. Various phases in the manufacturing process are discussed in some detail.

A GENERATOR FOR FAST NEUTRONS

621.384.6: 539.185.442

In the last few years interest has developed in the effects produced by fast neutrons, i.e. neutrons with a kinetic energy of the order of 10^5 or 10^6 electron volts. Such neutrons, like other types of corpuscular radiation, possess a strong ionizing action especially in media containing hydrogen and can therefore have a considerable effect on living matter and on substances consisting of large organic molecules.

While intense beams of slow neutrons can be obtained from atomic piles, the generation of high energy neutrons depends on particular nuclear reactions which take place in collisions of particles which have been accelerated to high energies. In the Philips Laboratory in Eindhoven, an apparatus has been developed which produces fast neutrons by means of the so-called D-D reaction:

$${}_1D^2 + {}_1D^2 \rightarrow {}_2He^3 + {}_0n^1 + 3.28 \text{ MeV}.$$

For this reaction, deuterium ions ${}_1D^2$ (heavy hydrogen nuclei) are accelerated by a high voltage and directed onto a target plate composed of a material rich in deuterium. In our neutron generator the latter consists of frozen D_2O, i.e. "heavy ice".

The accelerating apparatus (*fig. 1*) is based on a cascade generator which delivers a direct voltage which can be varied continuously between zero and 1 million volts. This generator, which is composed of a series of condensors and high voltage rectifiers, departs from the conventional design and is built as three columns around the porcelain tube in which the ions are accelerated. An ion source is situated at the upper end of the tube and connected to the high potential pole of the generator so that it is at a high positive potential with respect to earth.

The ions are produced here by an auxiliary discharge in deuterium gas at low pressure. The discharge is maintained by a high frequency alternating voltage. The power needed for the source is supplied by a small dynamo, driven via an insulating belt by a motor mounted by the earthed foot of the cascade generator (see fig. 1). A special feature of the cascade generator is that instead of thermionic valves, selenium rectifiers are used (nominal peak inverse voltage 250 kV each); these require no heater current, so that the well-known problem of supplying heater current to valves which are at a high potential does not arise. The accelerating tube is built up of five accelerating sections, the electrodes of which are of such a form that they focus the beam of downward directed ions. The ion current can be regulated between zero and a maximum of 1200 μA.

The target plate consists of a hollow copper disc, the edge of which is kept covered with a layer of heavy ice. The layer need not be more than about 20 μ thick, i.e. about the penetration depth of deuterium nuclei of 1 MeV energy in heavy ice. The temperature of the ice surface may not rise above about — 100 °C, since the vapour pressure of the heavy water would then be too high for proper functioning of the acceleration tube. The hollow target is therefore filled partly with liquid nitrogen, which continuously evaporates and so provides the necessary cooling. To avoid local overheating of the ice by the narrow ion beam, the beam is made to trace Lissajous figures on the ice surface (tracing

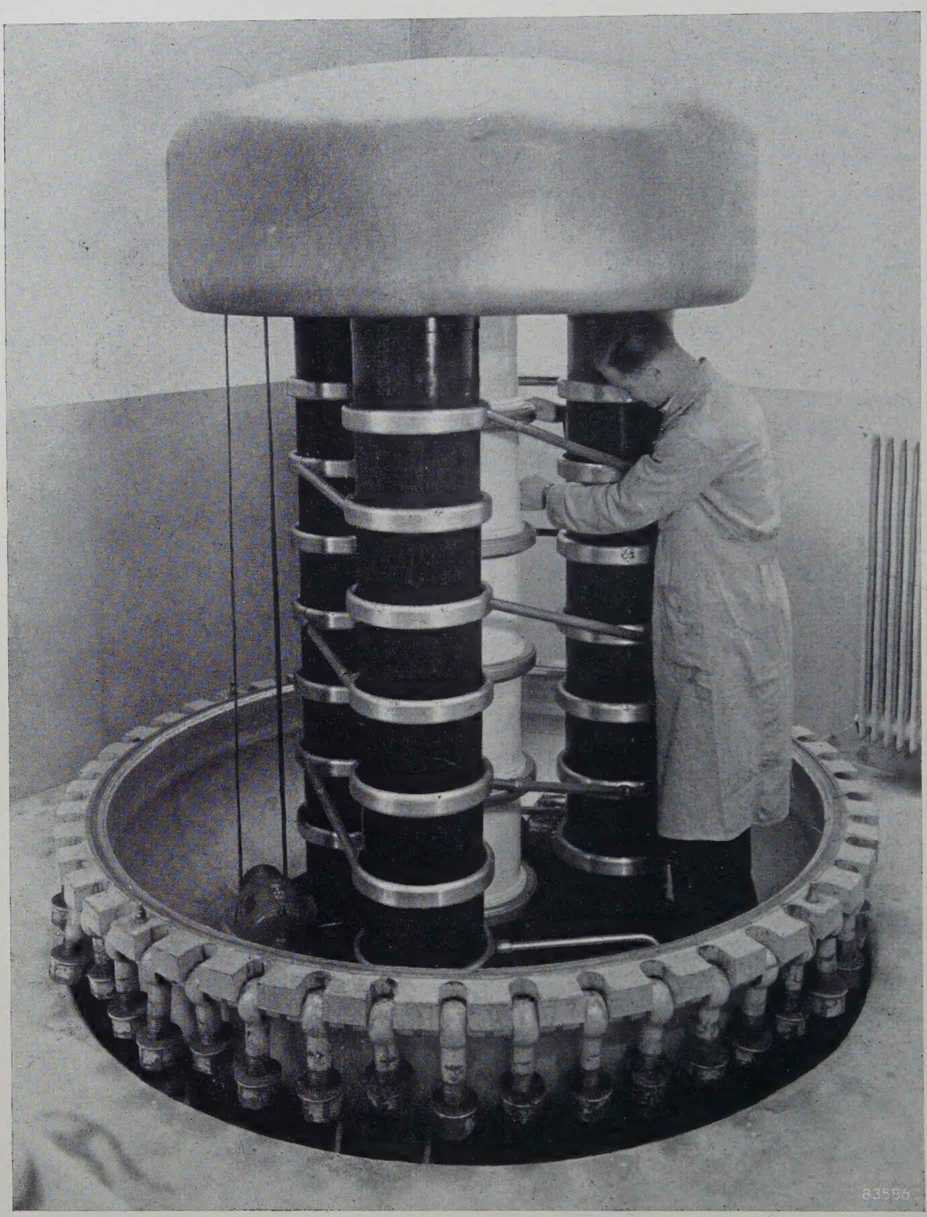

Fig. 1. 1 MeV cascade generator, arranged in three columns around the porcelain acceleration tube. Left, insulating belt which drives the dynamo for supplying the ion source and other auxiliary apparatus.

The cascade generator and the accelerating tube take up comparatively little space, since they are placed in a steel drum, three metres high, in which nitrogen at a pressure of 10 atm. provides the insulation. The pumps which maintain the high vacuum in the acceleration tube, are mounted at the bottom of the drum (*fig. 2*). This photograph is taken one floor lower than the room in which the generator stands, and shows also the earthed end of the acceleration tube and the target.

speed a few hundred m/sec) and the target is rotated (peripheral speed 8 m/sec) about a shaft introduced through the wall of the vacuum vessel and driven by a small electric motor. The shaft is hollow and through it the evaporated nitrogen escapes from the target and liquid nitrogen is supplied (*fig. 3*). These measures make it possible for about 500 W to be continuously dissipated on the layer of ice. At a voltage of 1 MeV, therefore, the ion current can be raised to about 500 μA.

It has been shown that with this neutron generator a continuous flux of 10^{10} neutrons per second can be obtained for many hours at a stretch. The neutrons leave the target in all directions through the walls of the target chamber. The neutron intensity is greatest in the direction of the ion beam. The neutrons also have the highest energy in this direction, viz. at the maximum ion acceleration voltage, about 4 MeV.

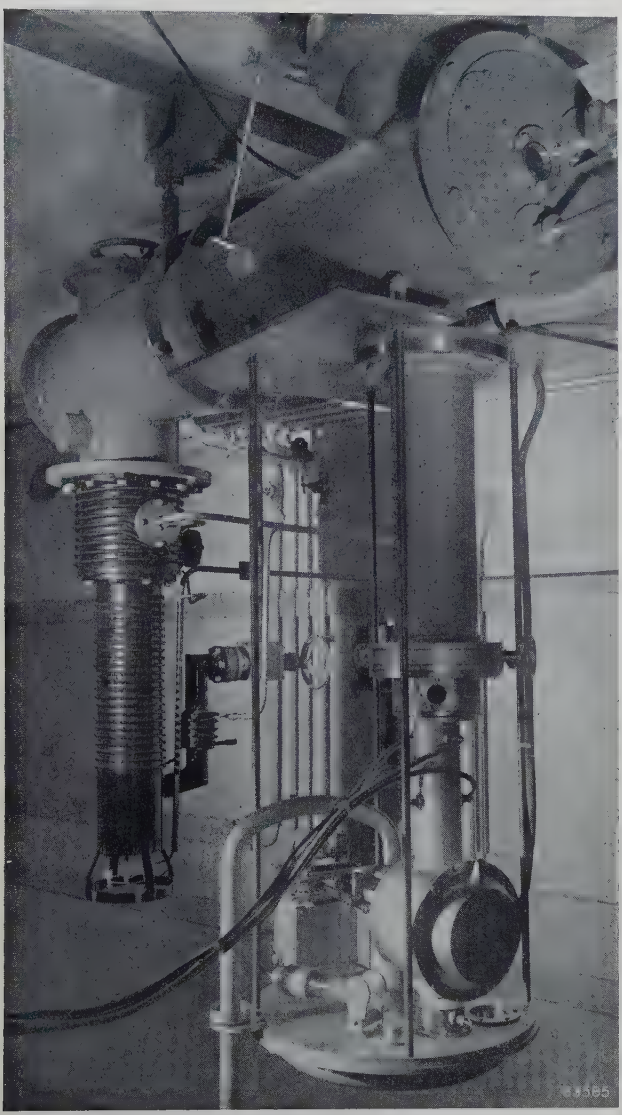

Fig. 2. The earthed lower end of the acceleration tube (a floor lower than in fig. 1). In the background is the pump installation which maintains the high vacuum in the acceleration tube.

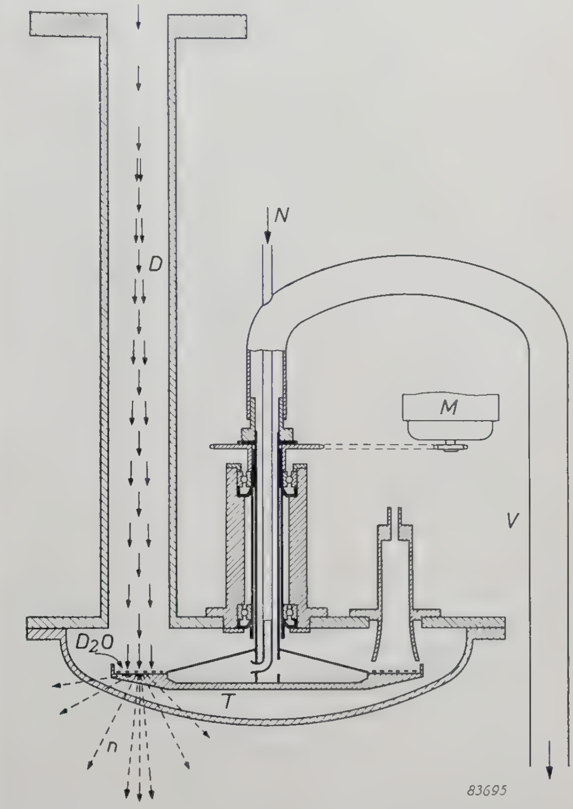

Fig. 3. Cross-section of the lower end of the acceleration tube, with hollow target *T* and its hollow axis of rotation. *D* deuteron ion beam, D_2O layer of heavy ice, *n* neutrons produced, *M* electric motor, *N* supply of liquid nitrogen, *V* chimney for extracting the evaporated nitrogen.

A. C. van DORSTEN.

THE "SYMMETRIX", A UNIVERSAL TABLE AND STAND FOR X-RAY DIAGNOSIS

by J. J. C. HARDENBERG and H. W. DUMBRILL *).

616-073.755.1

Many articles on the medical application of X-ray have been published in this Review, mostly concerned with physical and electrical problems: the production of the required X-rays, the X-ray tube supply, the quality of the X-ray image, the effect of irradiation upon human tissue, and so on. However, the actual radiological work also involves interesting mechanical problems, and the ultimate success of diagnosis or treatment depends quite considerably upon the ingenuity of the designer in solving these problems.

Introduction

In general, an X-ray diagnostic apparatus comprises five essential components: the X-ray tube; the H.T. generator; the control desk for the voltage and current of the tube, and the exposure[1]); a fluorescent screen or a film holder; and finally, the mechanical equipment, usually a universal tilting table, enabling the radiologist to position the patient as required. This equipment has been the subject of study for many years by mechanical engineers. This is a consequence of the development of many different methods of radiological examination, now in regular use in hospitals: clearly the equipment has to be designed to facilitate these procedures, which involve the examination of every part of the human body. The ease with which the radiologist can perform his task will evidently depend very largely upon the thought and precision embodied in the design of this equipment.

The requirements for the equipment are that the X-ray tube, fluorescent screen, film holder etc. must be movable to enable them to be positioned correctly in relation to the patient. It may also be convenient to be able to move the patient himself, the most common example being movement of the patient from a vertical to a horizontal position, which, by further rotation may then be converted into the so-called Trendelenburg position. In general, the X-ray tube, fluorescent screen, etc. should move with the patient so as to maintain the same relative position. This enables the radiologist to examine the patient not only in the vertical, horizontal, or intermediate positions, but also during the actual movement of the patient.

This technique is not employed in all countries. In Sweden, for example, separate examinations in the vertical and horizontal positions are usually preferred, and separate installations are employed for these examinations. However, in most countries so-called universal tables, suitable for the above-mentioned technique, are employed and are undergoing steady development.

Most of these equipments have a table turning about a horizontal axis. *Fig. 1* shows such a table in the horizontal position. The patient lies on top of the table; beneath it is the X-ray tube, which can be moved parallel to the table both longitudinally and laterally. Above the subject is the viewing equipment, that is, a fluorescent screen, usually combined with a serial cassette changer (described later). The viewing system is coupled to the X-ray tube in such a way as to follow its movement parallel to the table top. Moreover, the viewer is adjustable in a direction perpendicular to the table

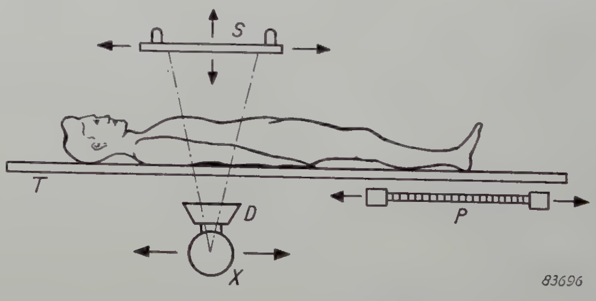

Fig. 1. Essential parts of a table for X-ray diagnosis. *T* table to carry the patient; *X* X-ray tube (with adjustable lead diaphragm, *D*, to limit the X-ray beam); *S* viewing system comprising a fluorescent screen and film-cassette; *P* Potter-Bucky diaphragm, and film-cassette employed in conjunction with an alternative separately mounted X-ray tube. The tube (*X*) can be moved parallel to the table, that is, in the directions indicated by arrows, and also at right angles to the plane of the drawing; the viewing system (*S*) moves with the tube, and can also be moved perpendicular to the surface of the table. The table top is made of a material of low X-ray absorption.

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*) Philips Balham Works, London.

[1]) Previous articles dealing with these components are: H. A. G. Hazeu and J. M. Ledeboer, A universal apparatus for X-ray diagnosis, Philips tech. Rev. **6**, 12-20, 1941; A. Nemet, W. A. Bayfield and M. Berindei, A diagnostic X-ray apparatus with exposure technique indication and overload protection, Philips tech. Rev. **10**, 37-45, 1949/1949.

top, to enable the radiologist to lower it as required to the patient (usually positioned with his back to the table) or even to employ the so-called compression technique (see later).

For some examination procedures, the table is used in conjunction with a second X-ray tube, mounted separately. Use is then often made of a so-called Potter-Bucky diaphragm to reduce X-ray scatter; this is fitted underneath the table as shown in fig. 1 [2]). The Potter-Bucky diaphragm must move or oscillate in a certain manner during the exposure. In addition, it must be adjustable to various positions beneath the table to enable different parts of the body to be radiographed. Accordingly, the designer must provide for all these movements.

Apart from speed and reliability, the various movements of the equipment must also be such that once the adjustment has been made, the observation or radiograph may be made immediately. For example, individual parts of the equipment must not vibrate at the moment that the exposure is made and so affect the sharpness of the picture. Again, an efficient braking system is required, to arrest the equipment at the instant that the desired position is obtained. Finally, all the movements of table, tube, film-holder, patient, etc. must be effected without undue effort on the part of the radiologist.

Principle of the "Symmetrix" design

It will be evident from the introduction that so many requirements are put on a universal diagnostic equipment that it is difficult to satisfy them all. Moreover, developments during the past 10 or 20 years have shown that whenever a new design appears on the market, users tend to add the new facilities provided by it to their list of requirements.

This was particularly noticeable after the second world war, when it was found that the design of mountings on the continent of Europe had followed somewhat different lines from those in England and America. In view of this, Philips set out to find a design to satisfy, as far as possible, the requirements of both schools of thought. This project led to the development of the "Symmetrix" mounting, now approved by radiologists in many countries. [3]) Essentially, this design is based on two ideas: *a*) the table movement comprises consecutive rotation about two separate axes. *b*) the two rotations are symmetrical with respect to the horizontal position; the table can be tilted from the horizontal to the vertical either to the left or to the right. With this arrangement is is possible to satisfy a large number of requirements.

The idea mentioned in *a*) is relatively new. To explain it, we shall now consider a conventional type of universal diagnostic table, which is adjusted to the different positions by rotation about a single axis. Such a mounting is, for example, the Philips "Diagnost". This has a centrally located base containing the drive, the table pivoting about a horizontal axis at the top of the base (*fig. 2*). The axis is so positioned as to leave enough space between it and the table top for the movement of the scatter grid mentioned above, and to enable to table to be adjusted to Trendelenburg positions up to roughly 10°.

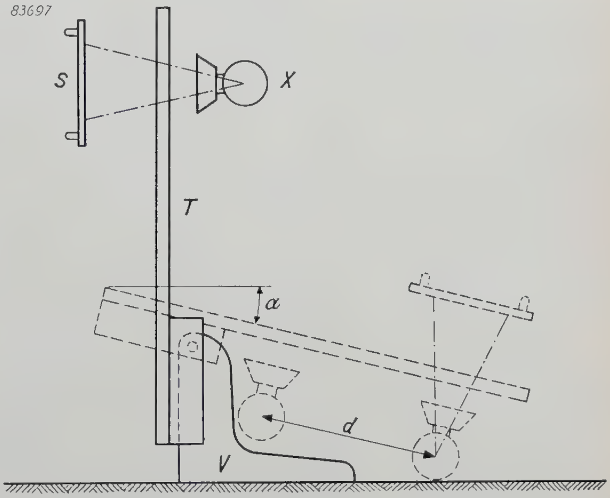

Fig. 2. Diagram of the Philips "Diagnost". The table (*T*) pivots on a spindle at the top of the central base (*V*). When the table is swung from the vertical to the horizontal position and beyond it (Trendelenburg position), there is a risk of the X-ray tube coming in contact with the floor; hence it is necessary, even for relatively small Trendelenburg angles (α), to fix the axis of rotation relatively high above the floor, Moreover, owing to the presence of the central base containing the spindle, the X-ray tube can be moved only a short distance (d) along the table.

Although satisfactory in many respects, the design of this stand satisfies the requirements only to a limited extent. Firstly, the central base limits the longitudinal movement of the X-ray tube under the table; secondly, the adjustment of the table to the Trendelenburg position involves a risk that the tube will touch the floor, and to avoid this it was necessary, even with the relatively small angle of 10°, to mount the table at a level somewhat higher than that which has been shown to be the most convenient.

In the "Symmetrix", this limitation is avoided by providing the table with two axes of rotation.

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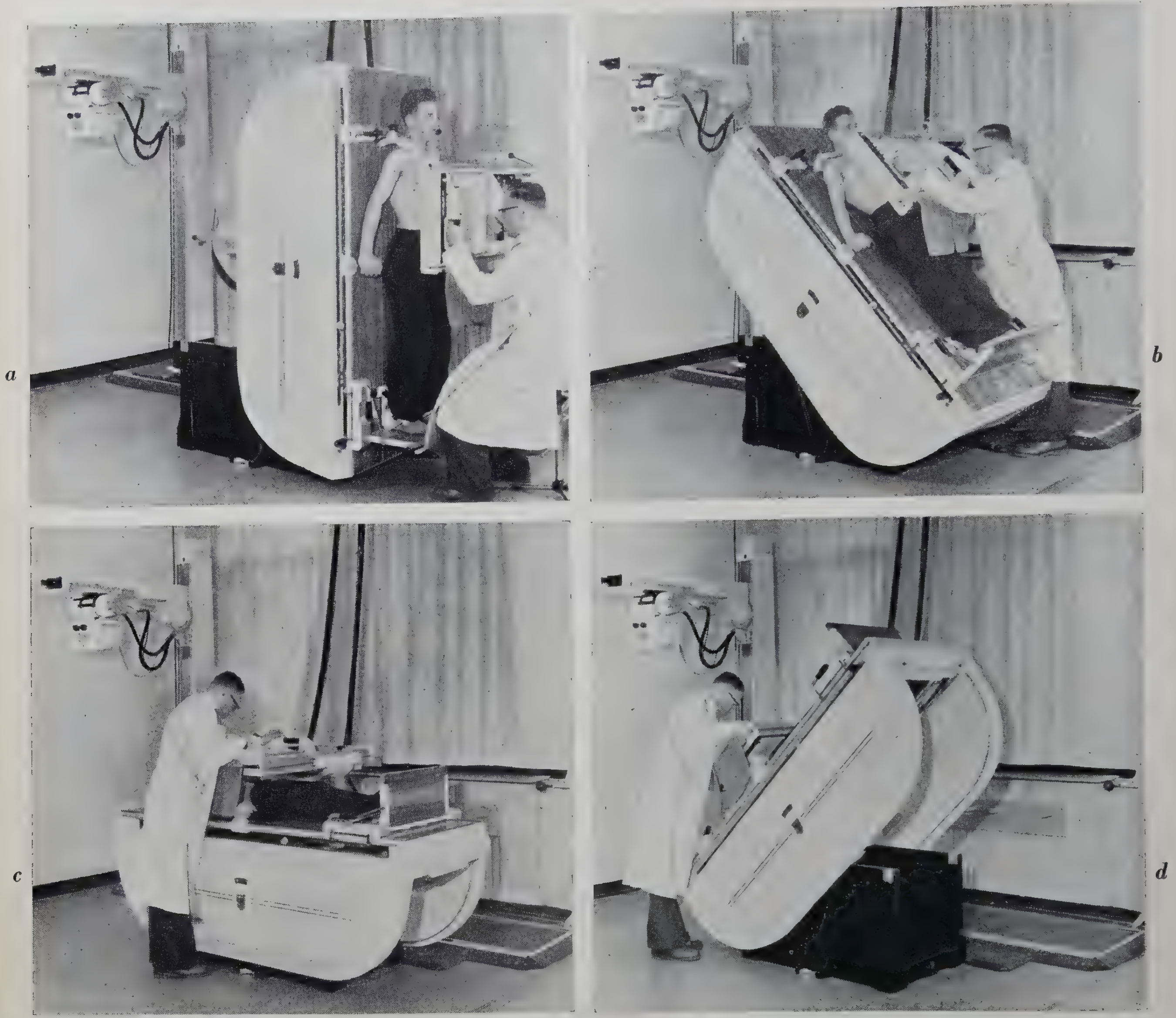
[2]) See W. J. Oosterkamp, Eliminating scattered radiation in medical X-ray photographs, Philips tech. Rev. **8**, 183-192, 1946.

[3]) The design of the "Symmetrix" is based on a tilting table developed and produced by the Philips factories at Balham.



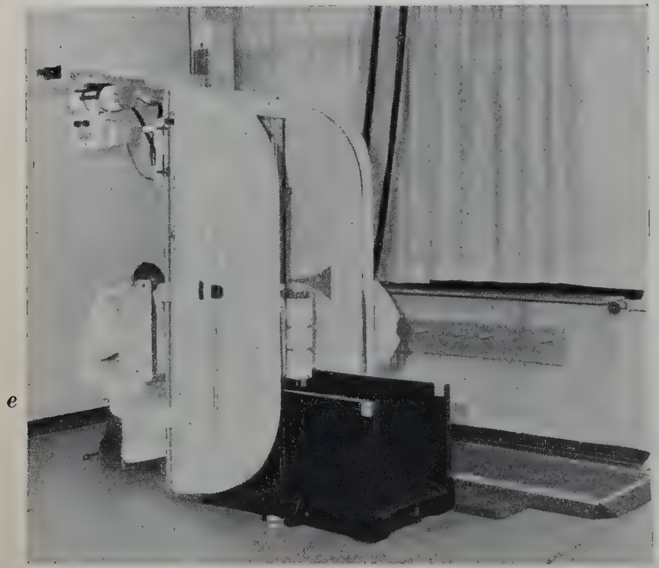


Fig. 3. The "Symmetrix" examination table can be rotated from the one vertical position (*a*) to the horizontal position (*c*) and thence to the opposite vertical position (*e*). In spite of this, the surface of the table in the horizontal position is only $32^1/_2$ inches above the floor.

The table swings from the vertical to the horizontal position about one of these axes; beyond the horizontal position it does not continue its original downward movement but instead it swings about another axis, displaced horizontally with respect to the first. In this way, the tube is prevented from coming too close to the floor. This enables the table to be placed at a virtually ideal level, i.e. $32^1/_2$ inches, in the horizontal position and yet rotated to a 90° Trendelenburg position. The Symmetrix also allows the X-ray tube to be moved the full length of the table. This is made possible by employing a pair of pivots on either side of the table for each axis instead of two full-length shafts. *Fig. 3a-c* shows different stages in the rotation of the subject from the vertical, to a 90° Trendelenburg position, in which the two symmetrically places axes of rotation successively come into operation.

The symmetrical location of the two axes of rotation is the logical outcome of the demand for deeper and deeper Trendelenburg positions (30°, 45°, 60°, etc.). Such positions can, of course, also be obtained in other ways: some of the existing systems combine two rotary movements, others one rotary movement and a translation. However, we consider that our system offers a considerable advantage as compared with these possibilities, in that the left-hand and right-hand vertical positions are equivalent and so enable the radiologist to choose either of them as the normal position for handling the patient.

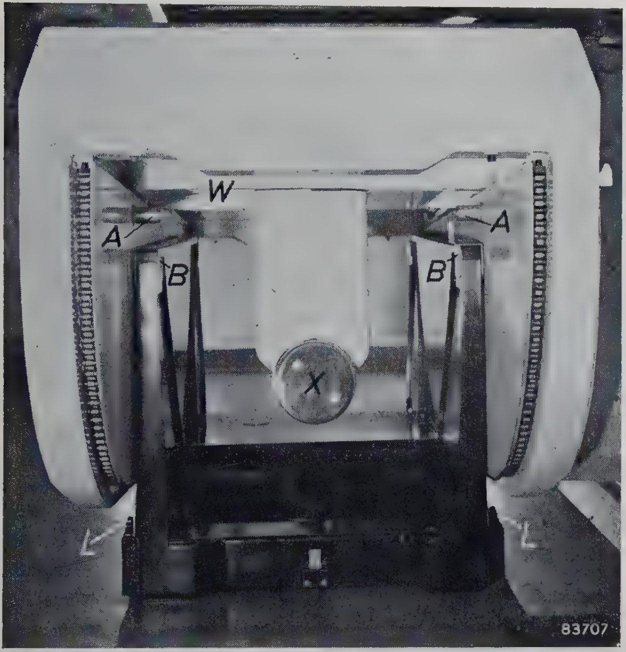


Fig. 4. End view underneath the "Symmetrix" with the table tilted slightly about the axis of rotation at the far end of the table. Both alternative axes of rotation consist of a pair of short spindles which turn in open bearing bushes at the top of the base walls. The spindles (*A*) at the near end of the table have just left their bushes (*B*). The use of short spindles in place of long shafts leaves the space under the table entirely free from obstructions and therefore enables the carriage (*W*) carrying the X-ray tube (*X*) to be moved the full length of the table underneath the patient. Note the two sprocket wheels (*L*, see fig. 6), one on either side of the base

It will now be clear that the principal feature of the "Symmetrix" table is that its axis of rotation changes from one pivot to the other when the table passes through the horizontal position. This is made possible by employing bearing bushes open at the top, enabling the one pair of pivoting lugs attached to the table to leave its bearings when the table begins to rotate on the other pair (*fig. 4*). The weight of the table is sufficient to prevent the spindles from leaving the bearings at the wrong moment.

Details of the "Symmetrix" table mechanism

Fig. 5 shows a cross-section of the "Symmetrix" table in the horizontal position. It is seen that the general profile of the base is U-shaped, and that the table fits over it as another, inverted, U.

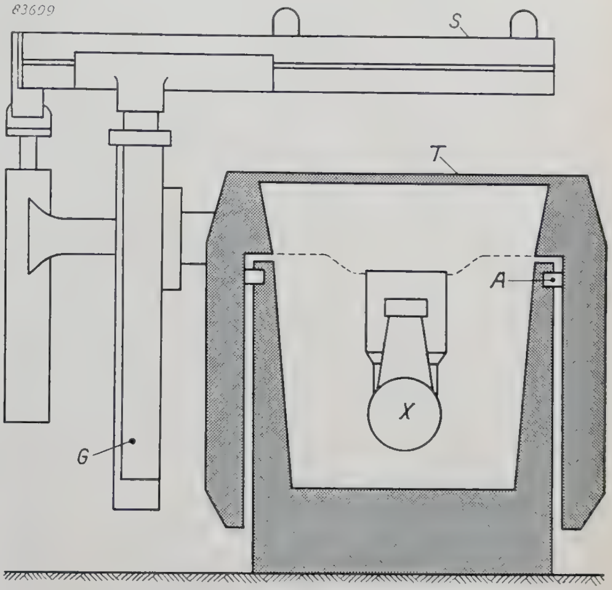


Fig. 5. Cross-section of the "Symmetrix" table. The base forms a U, over which the table, with its two sidewalls, fits as an inverted U. *G* is the mounting of the viewing system *S*. For the other letters see fig. 1 and fig. 3.

The mechanism to tilt the table is shown diagrammatically in *fig. 6*. Two driving spindles rotating in bearings in the base are positioned almost perpendicularly below the two axes of rotation of the table. A single electric motor placed at the centre of the base operates both driving spindles simultaneously at the same speed and in the same direction. Gear wheels at both ends of the two driving spindles, outside the base, engage toothed segments attached

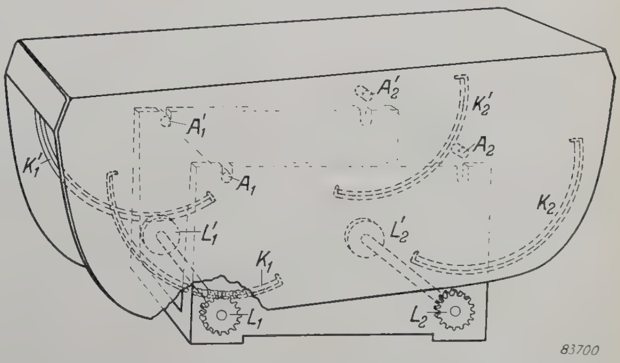


Fig. 6. Schematic drawing of the driving mechanism of the table. The table carries two heavy sprockets acting as toothed segments, K_1—K_1' and K_2—K_2', centring upon the two axes of rotation, A_1—A_1' and A_2—A_2', respectively. These sprockets engage with two pairs of sprocket wheels, L_1—L_1' and L_2—L_2', which are driven (at the same speed and in the same direction) by a centrally mounted motor (see fig. 9).

to the table and centring upon the respective axes of rotation. Except in the horizontal position, only one pair of toothed segments is engaged with the gear wheels. When the table passes the horizontal position, the pair of segments hitherto disengaged takes over from the other pair, the system being so designed that this transfer takes place without any interruption of the movement. In reality, ease of production and cost considerations have lead to the use of sprocket wheels instead of gears, and sprockets stretched round the quadrant-shaped ends of the table (see fig. 3), instead of the toothed segments.

The change-over of axis when the table is swung past the horizontal position can be explained more fully with the aid of *fig. 7*. The diagram shows the mechanism schematically, that is, the teeth of the wheels and segments are omitted in the drawing. Now, point P (fig. 7*a*), which will be the unique point of meshing at the moment of transition from the one pivot to the other, rotates first about axis A_1 and later, with the same angular velocity ω, about axis A_2. The peripheral velocity of rotation about the latter axis is $v_2 = h\omega$ (fig. 7*b*); the original peripheral velocity $v_1 = l\omega$ includes a component p in the v_2 direction. From the geometry of the figure we obtain

$$p = v_2\,(\cos^2\varepsilon - \tfrac{1}{2}\sin 2\varepsilon/\tan\alpha),$$

or, if the angle ε is small,

$$p/v_2 \approx 1 - \varepsilon/\tan\alpha.$$

It can be seen that p would be precisely equal to v_2 if $\varepsilon = 0$, that is, if each gear wheel operates in bearings vertically below its associated axis of rotation of the table. This then, is the condition to ensure continuous movement of the table in the theoretical case when the teeth of the wheels are ignored.

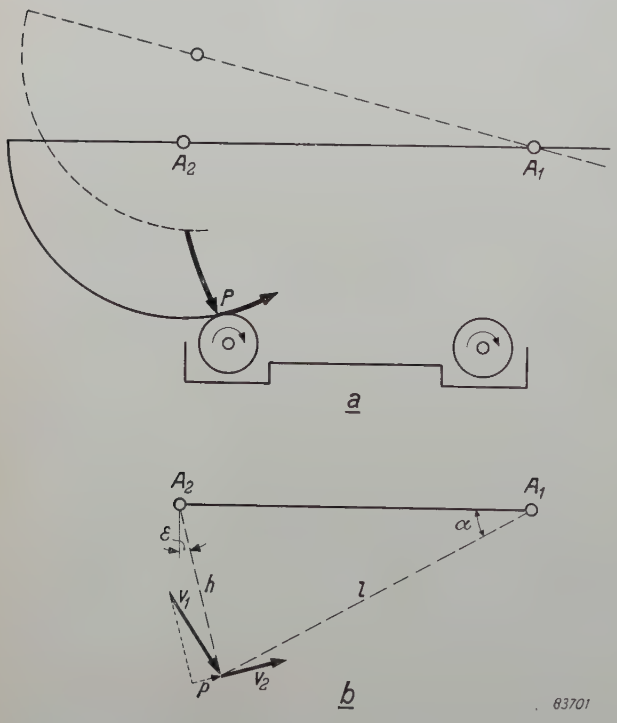


Fig. 7. Diagram illustrating the transition from rotation about axis A_1 to rotation about axis A_2.

In practice however, the teeth cannot be ignored. The changing of the pivot is then also governed by another important condition, that is, that the rollers of the sprocket engaging with the rotating sprocket wheel at point P must not scrape along the leading or trailing edges of the teeth on the sprocket wheel. To satisfy this condition it is necessary to make ε a small positive angle. In the "Symmetrix" $\varepsilon = 3°$. From *fig. 8*, illustrating the mating of the sprocket rollers and sprocket wheel teeth in three consecutive positions, it can be seen that in fact all the rollers clear the sides of the teeth by a small margin. This still occurs if the point of engagement of sprocket and wheel lies somewhat to the left or to the right of the position shown, as may well occur due to slight variations in the position in which the sprocket is mounted.

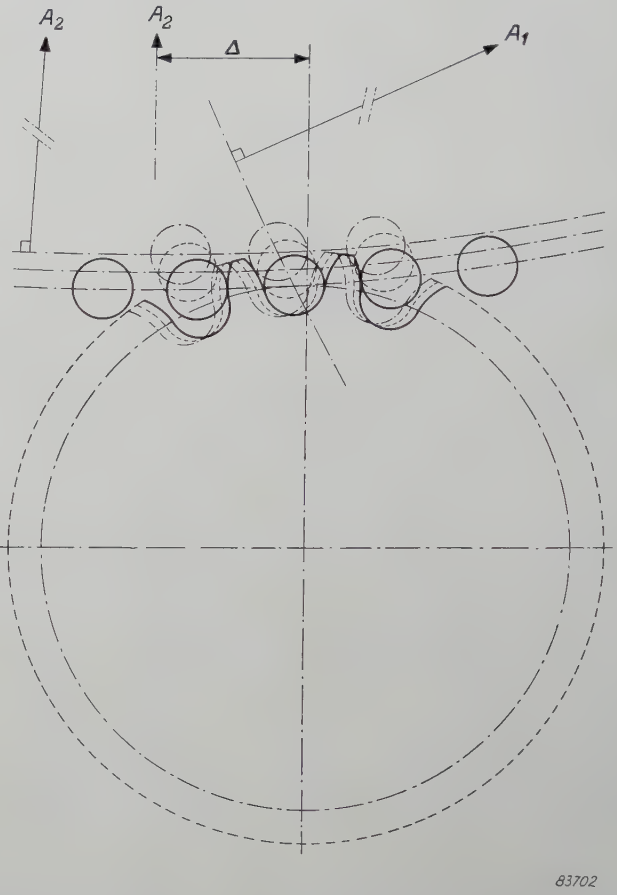


Fig. 8. The teeth of one of the rotating sprocket wheels and the rollers of the sprocket engaging with it (rotation about axis A_1), in three consecutive positions. Instead of being vertically below axis A_2, the sprocket wheel axis is displaced a certain distance (Δ) inwards.

A single-phase, two speed, reversible electric motor is employed, enabling the radiologist to swing the table either quickly or slowly in the desired direction by operating a foot switch, or a conveniently placed hand switch. The higher speed, employed, for example, to adjust the table when unoccupied, brings the table from the vertical to the horizontal position in 20 seconds; with the lower speed, used in certain examinations involving continuous viewing of the image of a moving subject, the table takes 40 seconds for this movement. To avoid an unduly perceptible jolt as the table swings past the horizontal position, owing to the fact that the vertical component of the motion of part of the table then reverses direction, feeler contacts are fitted in the bearing bushes to switch the motor automatically to the lower speed whenever one of the pairs of table pivots approaches its bearings (*fig. 9*).

To make the table top readily accessible for the positioning of the patient, whether in the vertical or the horizontal position, the mounting for the viewing unit runs on one side only of the Symmetrix (fig. 5). This mounting is constructed of light alloy and is fixed rigidly to the carriage carrying the X-ray tube. The whole assembly, guided by rollers, can be moved along the table. The viewing system, comprising a fluorescent screen and a serial film-cassette, is fixed on slides so that it can be moved both perpendicular to the table surface and across it. For the lateral movement, this system is normally coupled to the X-ray tube carriage by a telescopic connecting rod. By disconnecting this rod it is possible to push the serial cassette back far enough to all but clear the table surface. This is an advantage in that it facilitates the taking of radiographs with the separate X-ray tube with the Potter-Bucky diaphragm and cassette below the table (see next section).

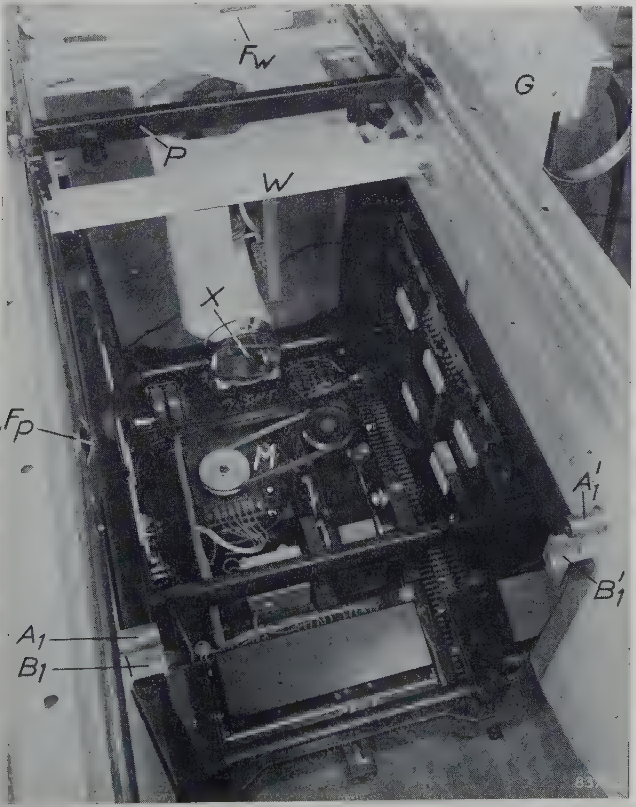


Fig. 9. Base of the "Symmetrix" table seen during assembly. M centrally mounted electric motor to drive the table: A_1, A_1' spindles and B_1, B_1' their associated open bushes. In B_1' there is a feeler switch which causes the table to rotate at the lower speed when passing throught the horizontal position; the switch operates through a relay system which is visible in the side wall of the base. *X* X-ray tube; *W* tube carriage with "concertina" cable (F_W); *G* mounting for viewing system; *P* frame of Potter-Bucky diaphragm, with concertina cable (F_P).

The X-ray tube and the viewing system coupled together may be adjusted a distance of 130 cm along the table, 30 cm across it and 35 cm in the perpendicular direction. Perpendicular movement of the viewing system when the table is in the horizontal position, is facilitated by a counterweight in the mounting. Movement of the viewing system and its counterweight and the tube carriage along the table when the latter is in the vertical position is also balanced by counterweights running along the side walls of the table (*fig. 10*).

Although this movement therefore involves virtually no work against the force of gravity, the setting in motion and stopping of such large masses would nevertheless mean that the radiologist had to overcome considerable forces if inertia. Accordingly, the longitudinal movement of tube and viewing system is driven, via sprockets and a friction and gear-wheel transmission by an auxiliary motor mounted at one end of the table. By pressing one of the lightly spring-loaded handles on the series cassette in the desired direction of travel, the radiologist closes a contact to operate the auxiliary motor in the appropriate direction. The motor thus drives the X-ray tube and viewing system in the same direction as the radiologist moves his hand. The torque-versus-speed characteristic of the motor is such as to ensure adequate initial acceleration of the masses to be moved: as the motor accelerates, the torque decreases until it is just enough to maintain the speed of movement usually required in practical examinations. This gives the radiologist the sensation that he is pushing the fluorescent screen and the cassette along the table by hand, with no more effort than is required to push them across the table. The latter movement is performed without the aid of a motor, since no counterweights have to be moved and therefore only relatively small inertia forces are involved.

The movable Potter-Bucky diaphragm under the table, referred to earlier in this article, is likewise provided with counterweights in the side-walls of the table to facilitate its movement along the latter.

Instead of balancing the viewing unit by means of counterweights, it would be possible to obtain the same effect by means of external springs; this would involve relatively smaller forces of inertia. However, we chose the above-mentioned method because it places less restriction on the positioning of the whole installation and does not impair the all-round accessibility of the table.

The flexible H.T. supply cables of the X-ray tube are carried along by the tube carriage as it moves along the table. A lateral guide passes them through the viewing system mounting to be drawn along by the tube as it moves across the table.

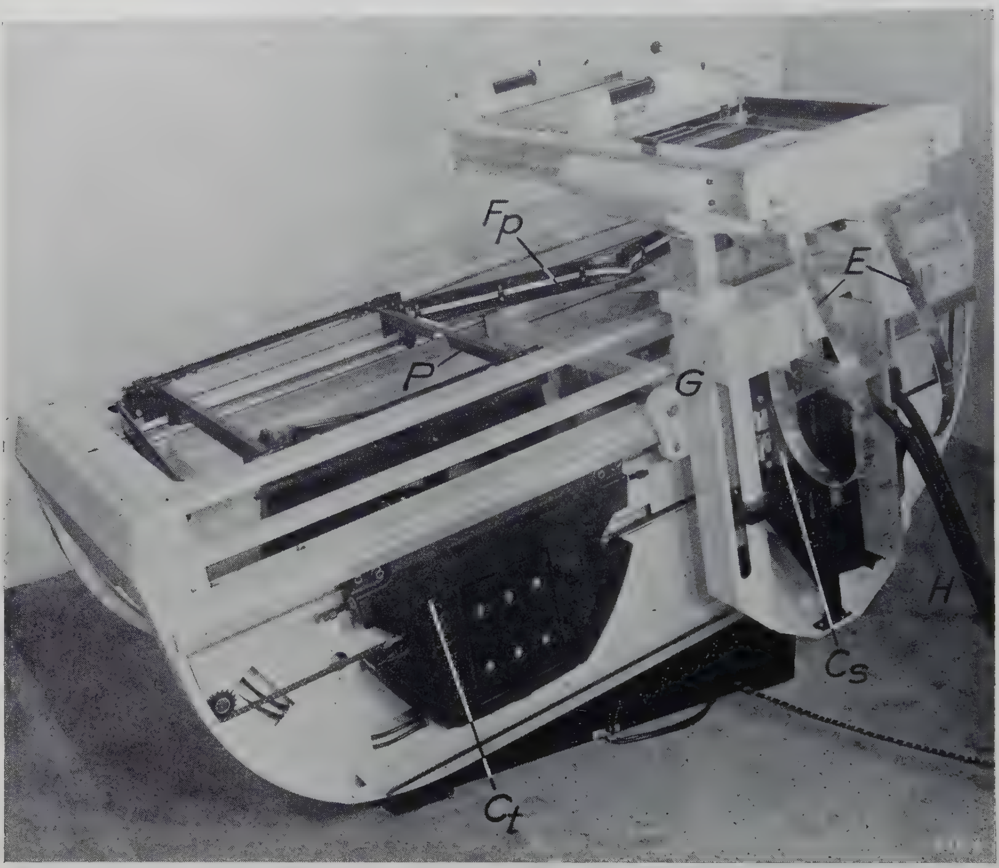


Fig. 10. The "Symmetrix" table during assembly. The table top, the side plates of the table and the cover plates of the viewing unit mounting G are not in position. C_s is the counterweight to to balance the perpendicalar movement of the viewing unit. One of the two heavier counterweights C_t employed to balance the movement of viewing unit and X-ray tube carriage along the table can be seen in the side wall of the table. H high-tension cables, passing through a lateral guide to the X-ray tube under the table; E flat multi-core cables connecting the controls on the viewing unit to the mounting; F_p concertina cable to connect the scatter grid P to the table (only the frame of P is shown).

The "Symmetrix" table countains a complex system of wiring to energize the motors and to connect motors, X-ray tube, etc. to operating contacts on the viewing system, in the base of the equipment and in a hand switch. The connecting cables are designed to follow the different parts of the table as they move in relation to one another. Since the movements of the viewing system and the tube carriage are only short, i.e. 35 cm perpendicular to, and 30 cm parallel to, the table surface, they are connected by two looped flat multi-core cables (E in fig. 10). The viewing system and the tube carriage are linked to the table by a cable attached to one or two hinged strips, following in the manner of a concertina (F_w in fig. 9); a similar system is employed for connections between the table and the Potter-Bucky diaphragm, which is movable in relation to the viewing unit mounting. Finally the tilting table and the fixed base are connected by a cable passing over spring-loaded rollers in the side-walls of the table which pay out the cable as the table tilts from the horizontal to the vertical position, and take up the slack as it returns to the horizontal position. The need for such a system arises, of course, from the fact that the "Symmetrix" is not provided with one permanent axis of rotation; otherwise, it would be possible to connect the table to the base by means of a straight, flexible cable close to the axis.

Mounting of the second X-ray tube

As stated in the introduction, there are certain methods of examination for which the X-ray tube incorporated in the table is not suitable. Important examples are chest radiography, in which the tube is placed quite a long way from the subject (say, 1.5 m), and the radiography of internal organs with the aid of the Potter-Bucky diaphragm, for which the subject must lie flat on the table, either prone or face upwards, and be irradiated vertically from above. Another example is planigraphy, a technique necessitating an altogether different arrangement of tube, subject and film.

In the case of the "Symmetrix", the second X-ray tube required for these and other techniques is mounted on a separate column, running on floor rails parallel to the table (*fig. 11*). In other designs ceiling rails are sometimes employed, either in conjunction with floor rails or alone. Although this enables the column to be dispensed with as an unnecessary obstruction, the many degrees of freedom and the corresponding counterweights which make up a rather heavy installation, would impose a severe strain on the ceiling. The floor rail system was therefore adopted, the rails being bedded in a low platform with sloping sides to prevent it from being a dangerous obstruction even in the dark.

The X-ray tube is mounted on a horizontal arm which can be moved up and down the column and rotated about its longitudinal axis. Since the column likewise rotates on its axis, and the X-ray tube can be moved to and fro along the arm, and also rotated about its own axis, the tube can easily be adjusted in relation to the "Symmetrix" table to obtain the required examination of the patient without the inconvenience of moving him. Moreover, the column-mounted X-ray tube can also be used to examine other patients on tables or stretchers arranged either in line with, or parallel to, the "Symmetrix" table. This combination of column and table therefore has some claim to be described as a universal mounting.

To facilitate the vertical adjustment of the tube, the arm and tube are balanced by counterweights sliding up and down in the column. To be within easy reach, the operating handles controlling the various movements are located at the tip of the arm. The X-ray tube is so mounted that the focus, from which the X-rays proceed, is on the geometrical axis of rotation of the arm. This is important in planigraphy In this technique, the X-ray focus and the cassette are moved in opposite directions parallel to the surface of the table, in such a way that the central ray of the X-ray beam always passes through a particular point inside the patient [4]). To satisfy this requirement it is necessary to turn the X-ray tube about the axis of the arm, and the above-mentioned arrangement enables it to be rotated without affecting the parallel movement of the focus. Fully automatic planigraphy with the subject horizontal (in which the pillar must move 1 metre along the rails in roughly 1 second) or upright (in which the arm must move 1 metre vertically in roughly 1 second) can be carried out by means of a separate auxiliary unit.

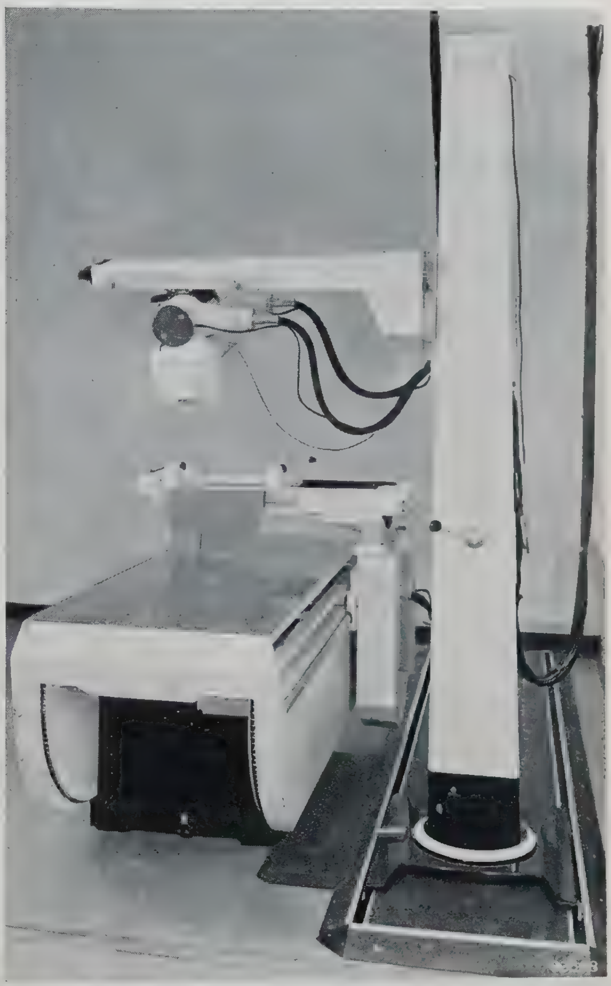


Fig. 11. Column carrying the alternative X-ray tube, for use with the "Symmetrix" stand. The column runs on double floor rails and rotates on its axis. The X-ray tube and its diaphragm are attached to an arm and can be moved to and fro along it. The arm rotates on its axis and can be raised and lowered on the column.

Practical application of the "Symmetrix"

Although it is beyond the scope of this article to go into all the operations involved in the various possible examinations with a universal diagnostic apparatus it may be useful to devote our concluding paragraph to a description of the procedure in carrying out a particular examination. Accordingly, the examination of the stomach by means of the serial cassette will now be considered.

The "Symmetrix" table having been adjusted to the vertical position, the subject walks up to it without having to stoop to avoid obstructions in the dark, stands against it (if necessary on a foot rest) and may be given barium meal to swallow. The radiologist, sitting in front of the fluorescent screen, studies the X-ray image. He is protected against direct X-rays by a sheet of thick lead-glass, and from radiation scattered in the patient by a lead cover and sheets of lead-rubber hanging from the screen (fig. 4). He also wears a lead-rubber apron; lead-rubber gloves are sometimes used to protect his hands. Two motors mounted on the shield of the X-ray tube and controlled by push-buttons beside the screen enable the radiologist to vary the rectangular aperture of a lead diaphragm situated in the X-ray beam, and so mask the image, as required. (The image should not be larger than is strictly necessary for the particular examination, in order to minimize the decrease in contrast owing to scattered radiation; see the article referred to in note [2])). Gripping the handles on either side of the screen, the radiologist moves it over the subject to find the best position for a radiograph; he does this without effort, since the vertical component of the movement, involving the movement of the viewing system, tube carriage and counterweights, is carried out for him by the auxiliary motor. The radiologist may palpate the subject by hand or with a suitable instrument, or push the screen forward to "compress" the subject by a special pad of low X-ray absorption attached to the other side of the screen (the adipose and other tissues are thus pushed aside as far as possible, so that they do not absorb and scatter X-radiation unnecessarily). When once the screen is suitably positioned and the proper phase in the assimilation of the contrast medium is reached, the radiologist clamps all the moving parts of the apparatus and takes the radiograph. All that he has to do to clamp the apparatus is to turn either of the two screen grips slightly on its spindle, thus applying electromagnetic brakes to all the moving parts. To take the radiograph, he merely presses a button; the tube voltage and current and the exposure, are preselected, usually by an assistant operating the control desk.

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[4]) See A. Bouwers, The localization of objects in the human body, Philips tech. Rev. **5**, 309-314, 1940.

The pressing of the button releases a spring-loaded slide to carry the cassette into position in front of the screen; as it moves, this slide closes a contact to prepare the X-ray tube for the load to be applied to it a moment later (the heater current then increases and the anode begins to rotate). If necessary, the same contact may be used to switch on an electric motor which oscillates a thin Potter-Bucky grid behind the screen. On reaching the end of its track, the slide closes another contact to switch on the tube H.T. for the pre-selected period. This completes the taking of the radiograph; the radiologist then pushes the slide back to its starting position, thus enabling the whole process to be repeated to record another phase of the stomach movements. The serial cassette is so designed that it automatically makes a series of exposures on the one standard-size film sheet; it may be adjusted to expose the film either all at once, or in 2, 4 or 6 equal parts.

A switch is provided on the serial cassette to enable the radiologist to tilt the table to certain angles indicated on a scale; in stomach radiography this facility is employed only in special cases, but it is important in certain other examinations.

Summary. The mounting of a diagnostic X-ray installation usually includes a movable examination table upon which the subject is placed, with an X-ray tube and viewing system (fluorescent screen, film-holder) mounted so as to enable the radiologist to position them as required in relation to one another. A certain widely used examination procedure involves turning the patient about a horizontal axis (at right angles to the X-ray beam) from the vertical to the horizontal position, and in some cases beyond it. During this movement the X-ray beam must tilt with the patient. The "Symmetrix" table described in the present article enables the subject to be tilted through 180° from the one vertical position to the other without limiting the movement of the X-ray tube along the table, and without the table having to be mounted too high above the floor. The essential feature of the design is that the table has two alternative axes of rotation, equidistant from the centre, which come into operation one after the other. Each axis comprises two short spindles turning in bushes which are open at the top, so that the pair of spindles not in operation may leave to permit rotation about the other pair. Two sets of counterweights are employed, the one to balance the viewing system as it moves perpendicular to the table, and the other in the side-walls of the table, to balance this system, together with its counterweights and the X-ray tube, when they are moved along the table as one unit. An auxiliary motor is employed to move the larger masses. The "Symmetrix" installation also includes a column, running on rails in the floor, carrying a second X-ray tube. The latter is provided with various degrees of freedom for use in certain important examination procedures.

ERRATUM

AN X-RAY TUBE FOR MICRORADIOGRAPHY

In *figs 3* and *4* of the above mentioned article (Philips tech. Rev. **17**, p. 46, Aug. 1955) the scale marks in the photographs should read 100 μ and 200 μ respectively instead of 10 and 20 μ.

A SIMPLE AND RELIABLE IONIZATION MANOMETER

by E. BOUWMEESTER and N. WARMOLTZ.

531.788.74

Since 1916, when Buckley constructed and described the first ionization manometer, a large variety of designs both of the manometer tube and of the associated circuits, have been devised. By a careful evaluation of the merits of the various systems, the authors have arrived at a combination of circuits and details which, though not in themselves original, form a reliable and accurate manometer.

Principle of the ionization manometer

Among the many methods for measuring low gas pressures [1]), within the range 10^{-2} to 10^{-8} mm Hg, the ionization manometer is still one of the most accurate instruments, and for its accuracy, the most convenient. Let us briefly recapitulate the principle.

The manometer head is mounted in a glass tube which is fused to the apparatus in which the pressure is to be measured. The tube contains as a rule three electrodes (*fig. 1*) viz. a cathode f, and two coaxially arranged electrodes a and c. The grid-like electrode a (the anode) is given a positive potential of, say, 100 V relative to the cathode, while the electrode c is given a negative potential of about — 40 V. The electrons are accelerated by the electric field between f and a. A number of them shoot through the anode and, in general, oscillate about it before impinging upon a. They therefore describe a path of considerable length, in the course of which they ionize some of the gas molecules within the envelope. The positive ions formed in the region between a and c, will impinge upon c, which is called the "ion collector" [2]).

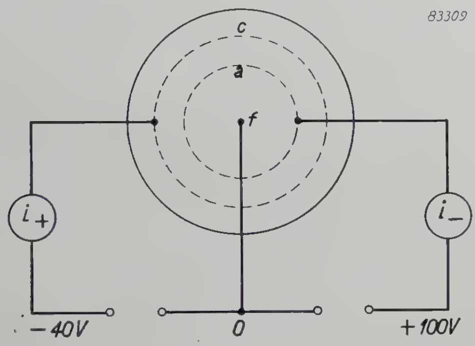

Fig. 1. Principle of the ionization manometer. The electrons emitted by the cathode f are accelerated by the anode a (which has the form of a grid), at which they finally arrive; they produce the current i—. The ions formed arrive at the ion collector c and produce the current i+.

The number of ions is proportional to the gas density and hence to the gas pressure, as well as to the ionizing electron current. If the latter is constant, then the current flowing from c is a measure of the gas pressure.

In designing an ionization manometer two essential problems present themselves: the adjustment and stabilization of the electron current, and the measuring of the ion current, which is generally very small (often of the order of 10^{-11} A). In this article we shall describe the design of an ionization manometer which has been used in the Philips Research Laboratories in Eindhoven and elsewhere for a considerable time (*fig. 2*) [3]).

This will be followed by a discussion of the calibration curves and of some of the measures taken to improve the accuracy at low pressures (down to 10^{-8} mm Hg).

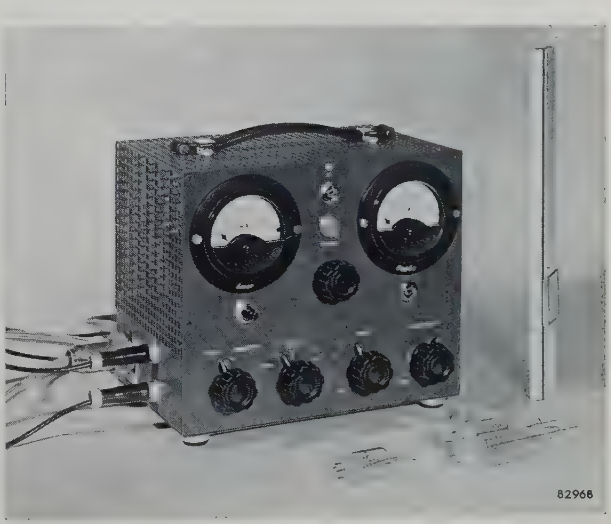

Fig. 2. The ionization manometer, showing two manometer tubes, one of a large and one of a small type.

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[1]) A systematic survey of these methods is given e.g. in F. M. Penning, Manometers for low gas pressures, Philips tech. Rev. **2**, 201-208, 1937.

[2]) Sometimes c is given the function of anode and a that of collector.

[3]) A short description of the instrument in an earlier stage of development was given by: N. Warmoltz and E .Bouwmeester, An easily degassable ionisation gauge, Appl. sci. Res. **B2**, 273-276, 1951.

Adjusting and stabilizing the electron current

If the anode potential is given a sufficiently high value, so that the saturation current of the cathode is used as ionizing electron current, then fluctuations of the anode potential do not influence the calibration. This, however, requires a circuit for keeping this saturation current constant at the desired value by automatic control of the filament current. A control of this kind as a rule requires an amplifying tube and two regulator tubes and is thus rather complicated. If the anode current is limited by the space charge, then the current is virtually independent of the cathode temperature (provided only that the latter does not drop so far that the current is again limited to the saturation current). Following C. G. and D. D. Montgomery [4]), we have applied an improved variation of the latter method. A grid *g* is fitted between cathode *f* and anode *a* (*fig. 3*). Together they form a triode, the anode current of which can be stabilized very simply by negative feedback via a suitable resistance in the cathode current. The potentials of control grid and anode are both stabilized by means of voltage-stabilizing tubes 85 A1, to + 85 and + 255 V respectively relative to earth. The ripple on the anode current, caused by the potential distribution along the directly heated cathode varying with the mains frequency, which amounts to 10-15% of the mean value without feedback, is reduced to 1-2% by the application of feedback.

The manometer has been calibrated for two values of the electron current, viz. at 0.5 and at 2.5 mA. The latter value is applied for low pressures, since then the sensitivity is approximately five times greater. These values, which can be read from meter M_1 (fig. 3), are adjustable by varying the cathode resistance by means of R_3. The configuration of the electrodes in the manometer has been so selected, that at these emission current values, the cathode *f* becomes slightly positive with respect to *g*.

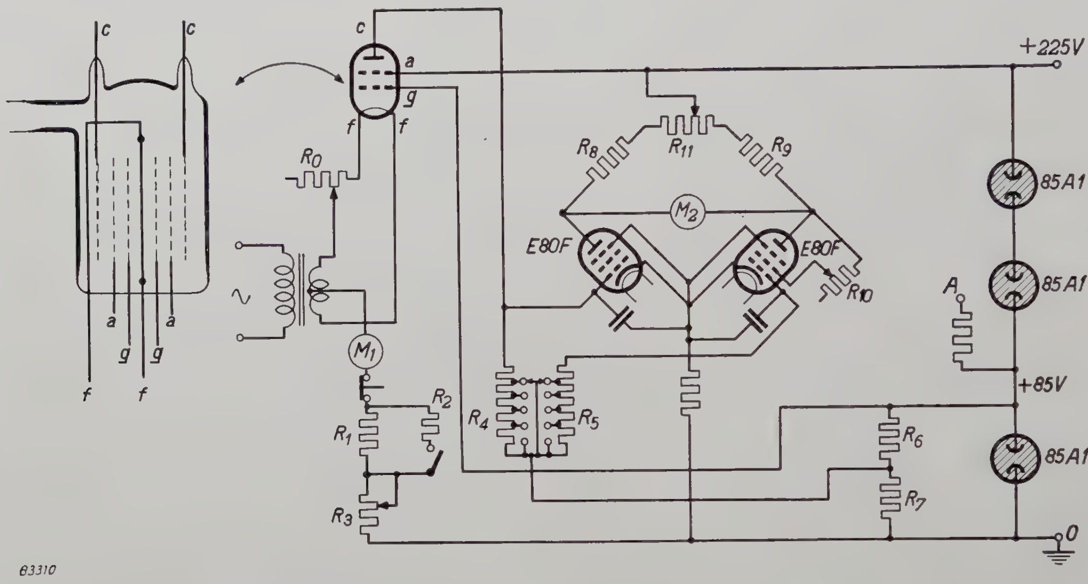

Fig. 3. Circuit diagram of the ionization manometer. The manometer tube is shown as a normal tetrode. The drawing on the left shows the tube more in its actual form. The glass wall is covered with an earthed conducting layer, except where drawn with thin lines. The meter M_1 is used for adjusting the ionizing electron current; the pressure is read from M_2.

The cathode saturation emission has to be adjusted by means of the filament current to a value slightly (e.g. 0.5 mA) in excess of the actual value of the emitted electron current. The cathode temperature required for this emission and, therefore, also the necessary filament current, however, depends on the work function of the cathode metal, which in its turn is considerably affected by the type of gas inside the manometer. Oxygen, for instance, has the effect of greatly increasing the work function (poisoning of the cathode); with the presence of this gas, therefore, the cathode temperature should be far higher than when the tube is filled, say, with pure argon. The necessary filament current, however, is not determined by the required cathode temperature alone. The loss of heat from the cathode to its surroundings, which depends both on the gas pressure and on the type of gas, also has an effect. It is thus obvious that the filament current necessary to give the required emission, depends on many variable factors. In order to avoid the risk of making the cathode temperature unnecessarily high and thereby shortening the working life of the cathode, it is desirable that the saturation emission can be directly indicated and adjusted. As shown in *fig. 4* this can be realized by temporarily reducing the cathode resistance, for this purpose the resistance R_2 can be shunted with R_1 (see fig. 3). The meter M_1 then indicates the saturation emission current. The filament current is subsequently adjusted by means of R_0, until the saturation emission has the desired value.

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[4]) C. G. and D. D. Montgomery, A grid-controlled ionisation gauge, Rev. sci. Instr. **9**, 58, 1928.

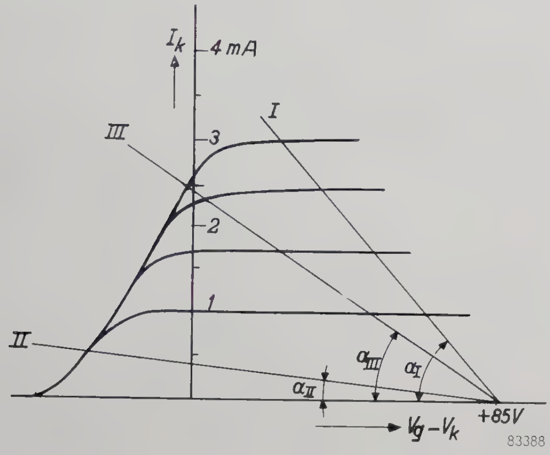

Fig. 4. The current I_k through the cathode circuit of the ionization manometer shown as a function of the voltage V_g—V_k between the control grid and the cathode, for various values of the saturation emission of the cathode, and at constant control-grid and anode potential (respectively + 85 V and + 255 V relative to earth). The working point of the triode so formed is given in the usual way by the point of intersection of the relevant characteristic with a straight line (the load line), passing through the point + 85 V on the abscissa. (This latter point is in reality considerably further to the right than shown in this schematic diagram.). The load line makes an angle α with the abscissa; cot α is a measure of the resistance between cathode and earth. If this resistance is low (R_2 connected in parallel to R_1, and R_3 completely short-circuited, see fig. 3), then the saturation current flows through the tube (load line *I*). If R_2 is switched off, cot $\alpha_{II} = R_1 + R_3$; the cathode current can now be accurately adjusted at 0.5 mA by means of R_3, (load line *II*). If R_2 is switched out, the load line can be placed in position *III* by means of R_3, provided the saturation emission is sufficient; the anode current now amounts to 2.5 mA.

Measuring of the ion current

The ion collector *c* is connected, via the resistor R_4 (fig. 3), to a point having a potential of approximately + 42.5 V relative to earth ($R_6 = R_7$). The collector is, therefore, 212.5 V negative with respect to the anode and therefore attracts the positive ions formed beyond the anode.

The voltage produced across the resistor R_4 is applied to the control grid of a pentode E 80 F, and governs the current through this tube. The resistor R_4 is adjustable to five values, each differing by a factor of 10. For each value of the electron emission current, therefore, five measuring ranges are available.

The current through the pentode, however, is not directly used to indicate the ion current. The change in anode current due to change in the gas pressure is very slight and fluctuations of this current, e.g. due to insufficient stabilization of the supply voltages, would cause grave errors in the indication. This is prevented by incorporating the pentode in one of the branches of a Wheatstone bridge. Another pentode of the same type and the resistors R_8 and R_9 form the other arms of the bridge. The current through a microammeter M_2 (100 μA f.s.d.) connected between the anodes of the two tubes is a measure of the ion current and the corresponding pressure. Any fluctuations of the supply voltages have practically the same effect upon the two tubes and do not disturb the balance of the bridge. This method of measuring the ion current is due to Laferti [5]). Provisions are made to enable adjustment of the bridge, such that: 1) M_2 indicates zero (equilibrium of the bridge) if no ions are formed, which is the case when the ionizing electron current is interrupted by the switch under M_1; 2) the sensitivity has such a value that the indication of M_2 corresponds to the calibration curve (current through M_2 as a function of the gas pressure). The latter is effected by ensuring that with a given voltage on the control grid of the first pentode (obtained by connecting the calibration point *A* to this control grid), M_2 shows a certain deflection. In order to satisfy both the above conditions at the same time, two mutually independent adjustments are required, which are provided in this case by the variable resistors R_{10} and R_{11}. By means of R_{10} the screen-grid voltage of the second tube (and hence its characteristic) is adjusted, whilst R_{11} makes it possible to control the ratio of the two resistor-branches of the bridge. It has been found necessary to make sure that the grid resistors R_4 and R_5 of the two tubes have always the same value. Otherwise the voltages across the grid resistors caused by grid currents, mainly originating from positive ions from residual gas in both pentodes would disturb the adjustment after the instrument is switched over to another measuring range.

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[5]) S. Dushman, Scientific foundations of vacuum technique, J. Wiley, New York 1949, p. 361.

The calibration curves

The manometer tube is made in two types, one of 50 cc and one of 10 cc capacity (see fig. 2). The smaller type has been specially developed for measurements on vessels of small volume. *Fig. 5* shows the calibration curve for both types, for an ionizing electron current of 0.5 mA and for the gases argon and hydrogen [6]). The current measured increases somewhat more rapidly than proportional to the pressure. In the range of the higher pressures (a few times 10^{-3} mm Hg) the large type deviates rather more from the proportionality in the case of argon. This is probably caused by an incipient avalanche-effect. It does not however impair the usefulness of the large type in this range.

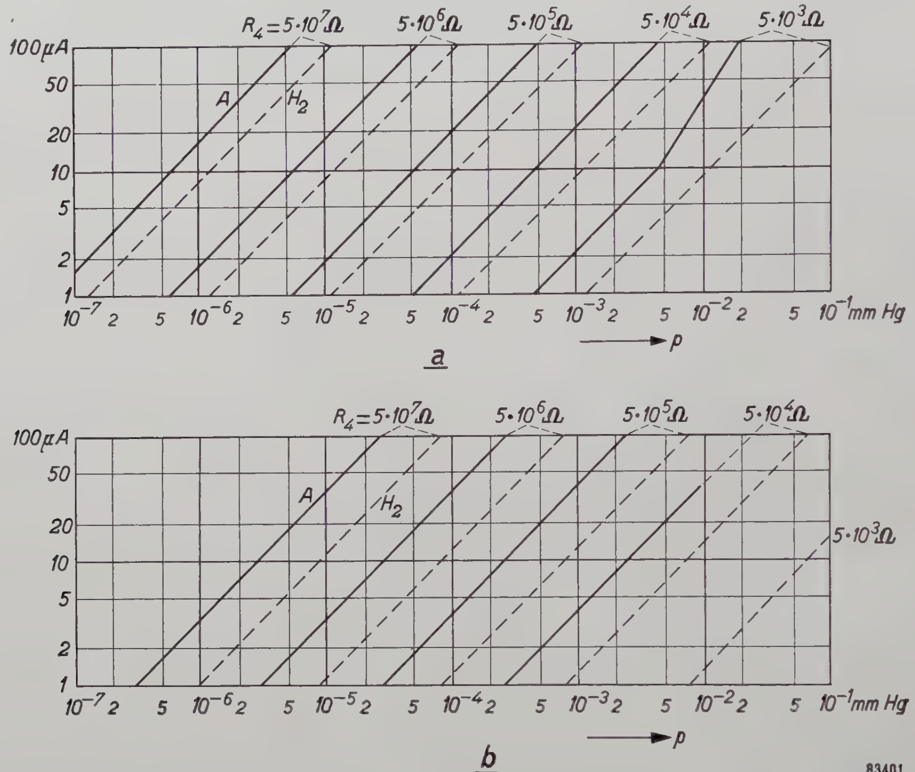

Fig. 5. Calibration curves for the large type of manometer tube (*a*) and for the smaller type (*b*). The full lines apply to argon (A), the broken lines to hydrogen (H_2). The ionizing electron current was 0.5 mA. The value of the saturation emission has some influence on the calibration at pressures higher than 5×10^{-3} mm Hg. In the present case the saturation emission was 1 mA. Both the pressure *p* and the current read from M_2 (see fig. 3) (not the ion current itself!) have been plotted logarithmically. Only a straight line with an slope of 45° then represents a linear relationship between pressure and current, so that with this instrument the current increases slightly more than proportional to the pressure. The values of the resistor R_4, corresponding to the various parts of the graphs, are included in the diagram. If the ionizing electron current is adjusted to 2.5 mA, pressures down to about 10^{-8} mm Hg can be measured. The ion current itself may be evaluated from the bridge sensitivity (760 μA/V) and the value of R_4.

The calibration curves as far down as 10^{-4} mm Hg have been obtained by comparison with an accurate McLeod gauge. For low pressures these measurements have been extrapolated.

Improvement of the accuracy at low pressures

During the development of this manometer one of the foremost aims was a sturdy and reliable instrument. We have, therefore, avoided sacrificing these properties for an extension of the measuring range to pressures below 10^{-8} mm Hg, which is the normal limit for this type of gauge. Some provisions have been made, however, to increase the accuracy and reliability of the indication in the lowest range:

1) The wall of the glass tube containing the electrode system is made internally conducting and earthed with the exception of the parts in the vicinity of the electrode lead-ins. Positive ions formed on the wall — where many adsorbed gas atoms are present — due to light from the incandescent cathode cannot now reach the collector since the latter is positive to earth. Moreover, the earthed wall precludes the accumulation of any wall charges, which might indeterminately distort the potential distribution inside the manometer tube, a most undesirable effect, particularly at low pressures.

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[6]) As is known (cf. the article referred to in footnote [1])), the calibration curve depends on the type of gas.

2) The ion collector is lead in through two protuberances on the head of the tube, designed to reduce leakage current between the collector and the other electrodes.

3) The ion collector takes the form of wide helix of fairly thin wire rather than a cylindrical plate, in view of the fact that at low pressures a disturbing effect is caused by the X-rays created by the electrons impinging on the anode. Part of this radiation reaches the ion collector and liberates electrons from it. In this way a current flows through the resistor R_4 which would be wrongly interpreted as an ion current. When the collector has the form of a helix the greater part of the radiation passes through the collector. The fairly thick lead-in wires of the collector are enamel-covered, to prevent their being hit by the X-rays.

This X-ray effect is one of the most important factors putting a lower limit to the measuring range of an ionization manometer. Alpert [7]), who was the first to adopt measures for suppressing this effect, used a very small and carefully situated collector and was thus able to measure pressures as low as 10^{-10} mm Hg.

4) Adequate de-gassing is particularly important when low pressures are to be measured. The three concentric electrodes (control grid, anode and collector), are mounted without supports, but each have lead-in wires at either end so that for de-gassing they can be heated by a current. For this purpose they can be connected together to a special winding of the supply transformer via a multiple switch (not shown in fig. 3). The various wire thicknesses and lengths of the grids are so chosen that during this process they all assume about the same temperature. They are made of molybdenum, which remains sufficiently rigid at high temperatures to prevent sagging of the grids. During the process of de-gassing, the filament may also be heated, and the envelope may be surrounded by a small furnace or heated in a gas flame in order to liberate the gas from the glass wall.

In order to obtain an idea of the influence of the above-mentioned X-ray effect, we have combined the ionization manometer with a mass spectrometer into a closed unit. A mass spectrometer can in principle be regarded as a sort of ionization manometer (*fig. 6*): here, too, the ion current impinging upon the collector is a measure of the gas pressure. In a mass spectrometer, however, the collector is so situated that it cannot be reached by X-rays from the anode.

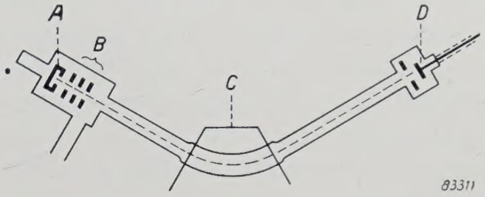

Fig. 6. Principle of a mass spectrometer. The gas to be analyzed, under low pressure, fills the entire spectrometer and is, therefore, also present in the ionization chamber *A*, where an electron current perpendicular to the plane of the drawing ionize the gas molecules. The ions thus formed are accelerated by the accelerating and focussing electrodes *B*. The magnet *C* produces a field perpendicular to the plane of the drawing, and is so adjusted that ions of the desired component of the gas impinge upon the collector *D*.

The mass spectrometer was first calibrated as a manometer in the range 10^{-4} - 10^{-7} mm Hg by comparison with the ionization manometer, the system being filled with argon. (It was known that this mass spectrometer was capable of measuring pressures down to 10^{-12} mm Hg.) By prolonged pumping of the system, the pressure measured with the mass spectrometer reached about 10^{-9} mm; nevertheless the ionization manometer did not indicate lower than about 10^{-8} mm Hg. This, therefore, constitutes the limit of the measuring range for this type of manometer.

Summary. An ionization manometer with four electrodes is described. The ionizing electron current is stabilized by means of a grid at constant potential placed near to the cathode and a high resistance in the cathode circuit. The ion current is measured with a Wheatstone-bridge, two of whose branches consist of pentodes (E 80 F), the other two branches being resistors. The ion current passes through the control-grid circuit of one of the pentodes, thus unbalancing the bridge. A microammeter serves as the indicating instrument. Some measures for improving the accuracy at low pressures are discussed. The measuring range extends from about 10^{-2} mm Hg to approximately 10^{-8} mm Hg. The lower limit is restricted by the fact that under the influence of X-rays from the anode, electrons are liberated from the collector.

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[7]) D. Alpert, New developments in the production and measurement of ultra high vacuum. J. appl. Phys. **24**, 860-876, 1953.

ABSTRACTS OF RECENT SCIENTIFIC PUBLICATIONS OF N.V. PHILIPS' GLOEILAMPENFABRIEKEN

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2184: Y. Haven and J. H. van Santen: Electrically and elastically active relaxation modes (J. chem. Phys. **22**, 1146-1147, 1954 (No. 6)).

An assembly of particles, each of which can move about in a system of potential wells separated from each other by energy barriers, proceeds toward the equilibrium distribution with a velocity given by a sum of exponential functions of time, i.e. there are a number of relaxation modes. The number of the relaxation modes and their symmetry properties are briefly discussed. For charged particles, some relaxation modes correspond to a change of electric moment (electrically active modes) while other modes correspond to redistributions of the particles that can be brought about by mechanical means (e.g. hydrostatic pressure, stretching or shear stresses). Some examples are given.

2185: J. M. Stevels: Iron in glass (Proc. Int. Comm. Glass **1**, 68-76, 1154).

Agreements and discrepancies are outlined concerning the explanations of the colour of iron-containing glasses. Proposals are made to introduce a "language" to be used in glass technology to describe the problems in a more general way, without reference to pre-conceived theories. The situation in a glass may probably be described by three parameters, namely: a structural parameter, α, which describes approximately how the rest of the network influences the position of the iron in the network; a reduction parameter, β, which indicates to what extent the glass is oxidized or reduced; and an electronic energy parameter, γ, which defines the ease with which electrons move within the medium consisting of oxygen ions.

2186: P. Baeyens: Electroplating with modulated current (to be published in Trans. Inst. Met. Finishing **31**, 1954).

A review of the many methods of electroplating with "modulated" current. The adjective "modulated" is proposed in this connection for a plating current that undergoes periodic variations in value or in sign. An extensive survey of the literature is given (excluding anodic oxidation and the formation of conversion coatings).

2187: H. P. J. Wijn: Quelques propriétés physiques des ferrites (Onde électrique **34**, 418-424, 1954, No. 326). (Some physical properties of ferrites; in French.)

After a brief survey of the chemical and physical properties of the ferromagnetic ferrites used in h.f. techniques, some special properties of ferrites are reviewed. The use of Ferroxcube as cores for high Q coils and for transformer cores is discussed. It is also shown that powdered ferrites can in principle be used at higher frequencies then the same material in solid form. Measurements of the magnetization curve of ferrites are given, from which conclusions may be drawn regarding the distortion caused by ferrite cores in circuits. Finally, a glass-enclosed ferrite ring having a rectangular hysteresis loop is described.

2188: J. S. C. Wessels: A possible function of Vitamin K in photosynthesis (Rec. Trav. chim. Pays-Bas **73**, 529-536, 1954 (No. 7)).

It is postulated that vitamin K plays a part as energy acceptor and hydrogen donor in photosynsthesis. Indications are given which may support this hypothesis. A possible function of Vitamin *K* in the process of oxidative phosphorylation is suggested.

2189: W. Elenbaas: Gasentladungslampen (Vakuum-Technik **2**, 36-42, 1954, No. 2). (Gas discharge lamps; in German).

Review of modern gas-discharge lamps, against the background of the physical processes involved. Low-pressure fluorescent lamps are dealt with first, with a short account of the concept of colour-rendering and colour-temperature. The conditions for the attainment of optimum efficiency in these lamps are also described. Increasing the vapour-pressure leads to increased efficiency of the discharge itself (i.e. without regard for the fluorescent powder coating). Lamps of this type (high and super-high pressure lamps) necessitate changes in construction and manufacturing processes, due to the increased loading of the discharge-tube walls and the resulting higher wall-temperature. A summary is given of the more common types of high and super-high pressure lamps being manufactured at the present time, together with their applications.

Of the remaining gas-discharge lamp types, sodium lamps are described, followed by a short discussion of neon lamps, and, finally, of neon sign lamps.

R 241: J. S. C. Wessels: Investigations on photosythesis; the Hill reaction, Part II (Philips Res. Rep. **9**, 161-196, 1954, No. 3).

Continuation of *R 240*. The possibility of the formation of free radicals in the Hill reaction is discussed. Neither polymerisation of acrylonitrile nor formation of phenol in the presence of benzene could be demonstrated. From this it is concluded that free radicals are either not present, or only present in very low concentrations. It appears that the standard potential of the compound concerned chiefly determines its suitability to serve as a Hill oxidant. The maximal reducing power of chloroplasts in vitro is highly dependent on the oxygen concentration. In an oxygen atmosphere, final potentials lower than about 230 mV were never attained, whereas the lowest final potential observed upon exclusion of oxygen was about zero. Redox systems with a negative standard potential, the reduction of which requires more energy than corresponds to one light quantum, are hardly reduced at all by chloroplasts. The theoretical and biochemical aspects of these results are discussed at length and a simplified scheme for the Hill reaction is proposed. The reaction mechanism can be interpreted satisfactorily by this scheme. The influence of a number of inhibitors upon the Hill reaction was investigated and some discrepancies occurring in the literature cleared up. The fact that the reaction rate is not influenced by *p*-chloromercuribenzoate and *p*-aminophenyldichlorarsine indicates that free SH groups are not essential for the activity of the chloroplasts.

R 242: K. F. Niessen: Spontaneous magnetization as a function of temperature for mixed crystals of ferrites with several Curie temperatures (Philips Res. Rep. **9**, 197-208, 1954, No. 3).

For mixed crystals of ferrites with more than one Curie temperature it is shown by an example how the spontaneous magnetization can be calculated as a function of temperature.

R 243: J. B. de Boer and A. Oostrijck: Reflection properties of dry and wet road surfaces and a simple method for their measurement (Philips Res. Rep. **9**, 209-224 1954, No. 3).

During the last 20 years or so, much work has been devoted to the study of the reflection properties of road surfaces. However, for the purpose of road lighting, the results published up to now are either incomplete or insufficiently accurate. Methods and equipment which have been applied up to now for the measurements of the reflection properties of road surfaces are rather complicated. The very simple means used by the authors for making measurements in the laboratory and in the field are briefly described. In this paper quantitative data are given on the reflection properties of a number of road surfaces common in the Netherlands. These data have been given for those derections of light incidence and observation which are of importance in public lighting practice. They have been presented in a special diagram in order to enable the public lighting engineer to make calculations on the luminance of road surfaces in a quick and simple manner.

R 244: F. van der Maesen and J. A. Brenkman: The solid solubility and the diffusion of nickel in germanium (Philips Res. Rep. **9**, 225-230, 1954, No. 3).

Nickel produces rapidly diffusing acceptors in germanium, just as copper. Hall and resistivity measurements show the existence of a Ni acceptor level lying 0.23 eV above the valence band. On the basis of this picture, the solid solubility between 700 and 900 °C is derived from resistivity measurements. From these values and the liquidus curve of the phase diagram Ge-Ni, the distribution coefficients (k) at various temperatures are calculated. The distribution coefficient (k^*) of Ni at the melting point of Ge is calculated to be 1.8×10^{-6} according to a method of Thurmond and Struthers. The diffusion coefficient of Ni in Ge is measured between 700 and 850 °C; the activation energy of diffusion is found to be 21 kcal/mole. Annealing of a Ni-saturated Ge sample restores the original resistivity.

R 245: M. E. Wise: Converting a number distribution of particle size into one for volume or surface area (Philips Res. Rep. **9**, 231-237, 1954, No. 3).

A number distribution of equivalent radii of particles in a powder can be accurately converted into a distribution by volume or surface area, even if the data are highly and/or non-uniformly grouped. A formula is derived to do this and is applied to a microscopic analysis into a frequency distribution of radii between 1, $\sqrt{2}$, 2, $2\sqrt{2}$ 4,.........units.

R 246: C. G. J. Jansen, R. Loosjes and K. Compaan: The velocity distribution of electrons of thermionic emitters under pulsed operation, Part II. Experimental results and a tentative theoretical explanation (Philips Res. Rep. **9**, 241-258, 1954, No. 4).

The velocity distribution among electrons emitted by metallic and oxide-coated cathodes is investigated by means of the apparatus described in a previous paper (*R 207*). Both under square-pulsed and DC loads metallic cathodes emit electrons with a single well-defined velocity. BaSrO and SrO coated cathodes, on the other hand, show under pulsed operation a dispersion in electron velocities up to several hundreds of volts with spectra consisting of a set of more or less discrete lines. Under a DC load the same oxide coatings emit electrons with nearly uniform velocities, the spectrum consisting of one rather sharp line. When DC is added to a square-pulsed load the line spectrum gradually contracts into a single line when the proportion DC is increased. Coatings of BaO, ThO_2, and of a mixture of (BaSr)O and nickel powder give a one-line spectrum, although this line is less sharp than with metallic cathodes. The velocity spectra of (BaSr)O and SrO are explained by a high resistance in the surface layer of the coating which arises owing to the combined effect of the conduction through the solid material and through the pores. The occurence of discrete lines is tentatively attributed to the combined effect to the potential distribution in the surface layer, of secondary emission, and of the geometry of the pores. The effect of a DC load is ascribed to polarization in the oxide layer.

R 247: L. M. Nijland: Some investigations on the electrical properties of hexagonal selenium (Philips Res. Rep. **9**, 259-294, 1954, No. 4).

A short survey of the recent literature on selenium is given in the first section. The resistivity of polycrystalline, hexagonal selenium can be lowered by halogens and can be raised by thallium. No reliable data on fundamental quantities like hole densities and mobilities are found in the literature. Investigations on these subjects are described in the next sections. A method to purify selenium by evaporation near its melting point is developed High-frequency measurements of the conductivity of pure and of thallium-doped selenium samples are consistent with the assumption that polycrystalline selenium consists of rather well-conducting crystals embedded in badly conducting layers of more or less amorphous selenium. Thallium increases the resistance of the layers and does not or only slightly affect the resistance of the crystals. Measurements of the Hall effect and of the shunt resistivity vs. frequency of pure and of bromine-containing selenium samples point to the same layer structure. Bromine does not affect the resistivity of the crystals but lowers that of the layers. Single crystals prepared in a bromine-containing atmosphere have the same resistivities as pure crystals. The last section contains a discussion of the experimental results and points to a model with both amorphous and crystallized parts in the same selenium chain.

R 248: E. W. Gorter: Saturation magnetization and crystal chemistry of ferrimagnetic oxides, Part I (Philips Res. Rep. **9**, 295-320, 1954, No. 4).

Measurements of the saturation magnetization (σ) against temperature are carried out for a number of mixed crystal oxides with spinel structure. The results are in agreement with Néel's theory of ferrimagnetism: the resultant magnetic moment m is the difference of the moments of the tetrahedral (A) and octahedral (B) sublattices, either (a) with complete parallelism of the ionic moments inside each sublattice, or (b) with angles between the ionic moments inside one of the sublattices. The spinel structure is described in section 1.1; experimental and theoretical data from literature on cation distribution are summarized in section 1.2.